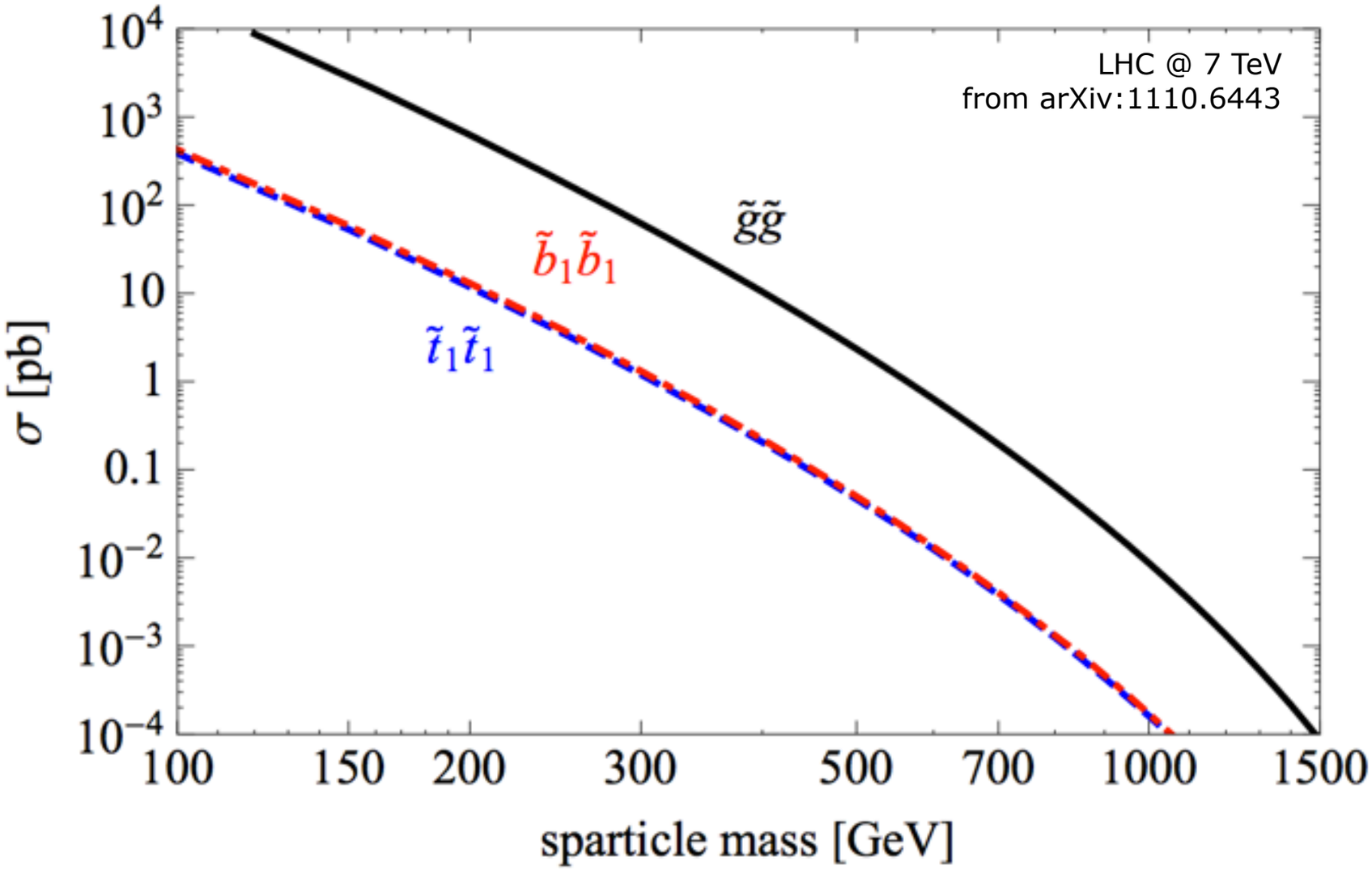
Stops and MET:
What's in shape?

Daniele Alves
FNAL

ICHEP'12 + work with M .Buckley, P. Fox, J. Lykken and C.-T. Yu (arXiv:1205.5805)

Santa Fe 2012 Summer Workshop

LHC @ 8 TeV: exciting times for stop searches



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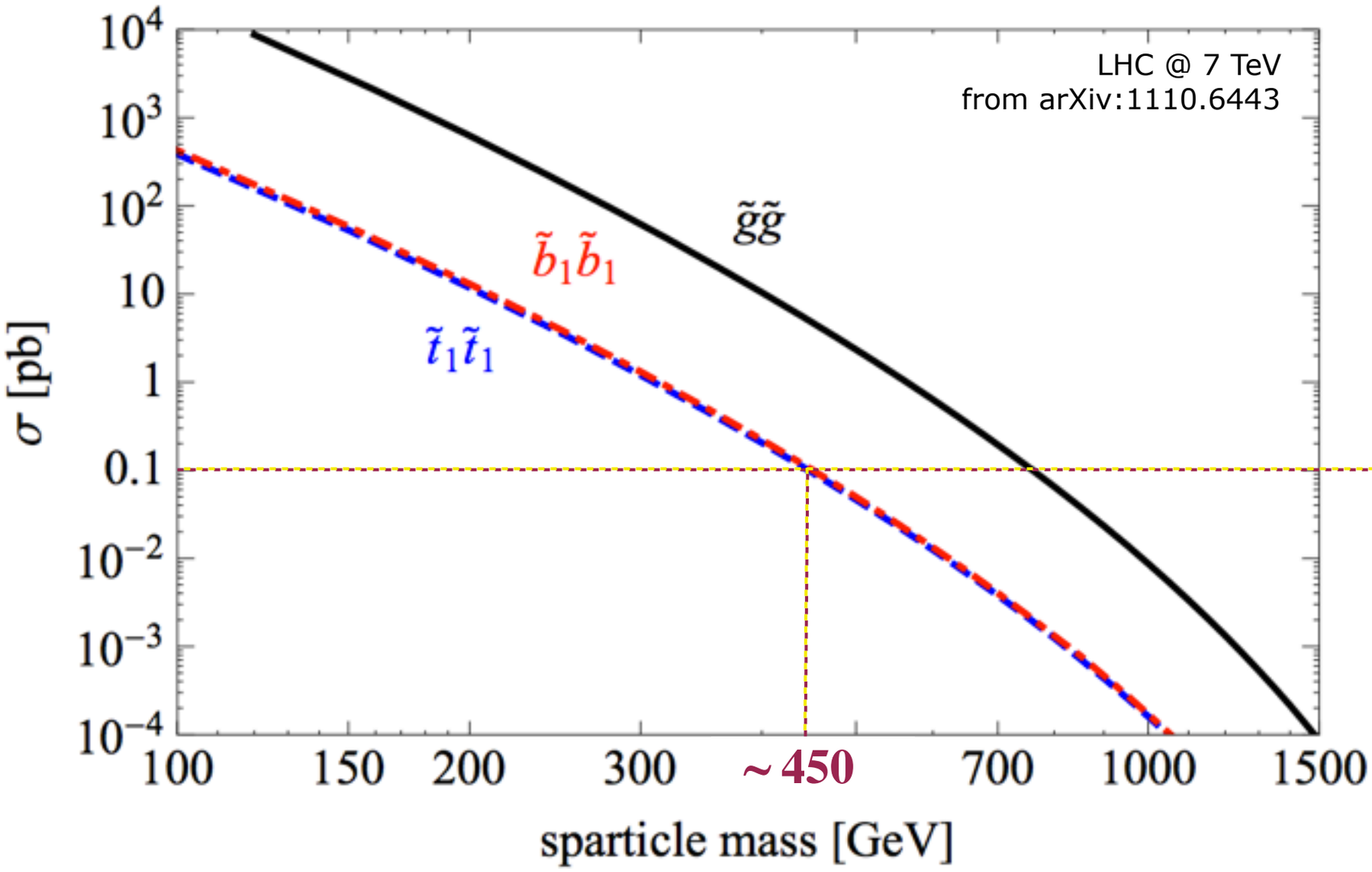
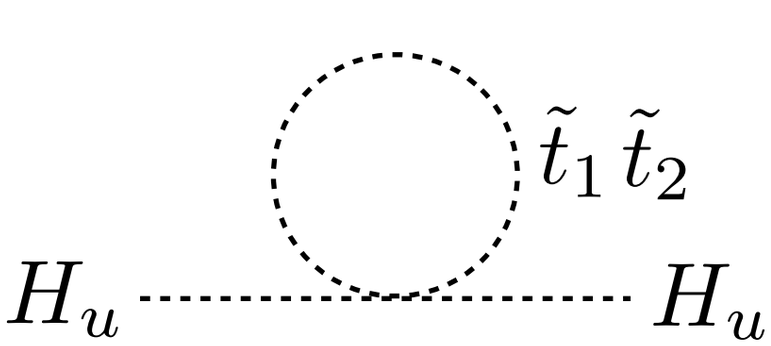


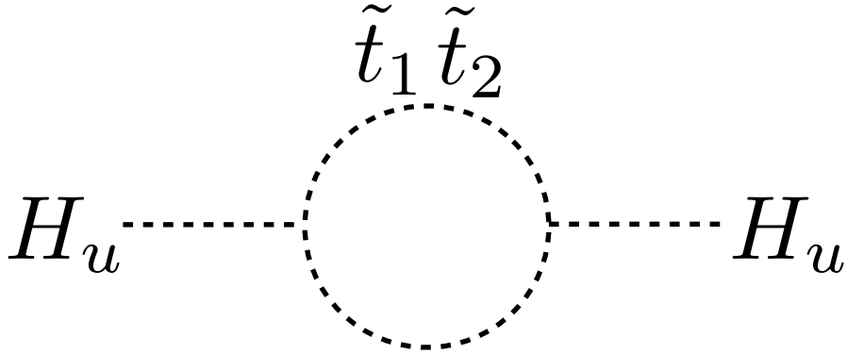
~ 500 events with 5/fb

LHC is starting to probe
direct production of 3rd generation squarks

First analyses just released at ICHEP'12 !

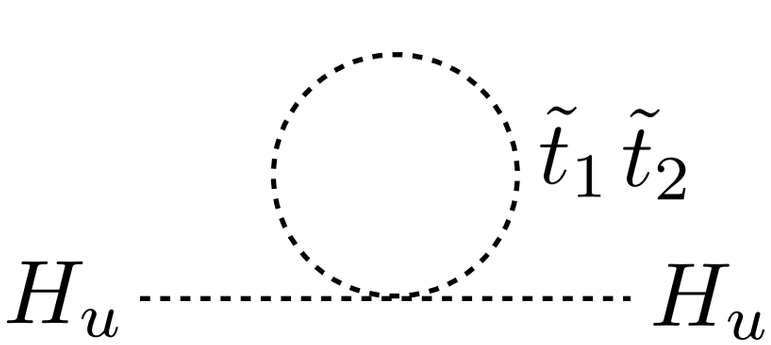
Light Stops and EW naturalness

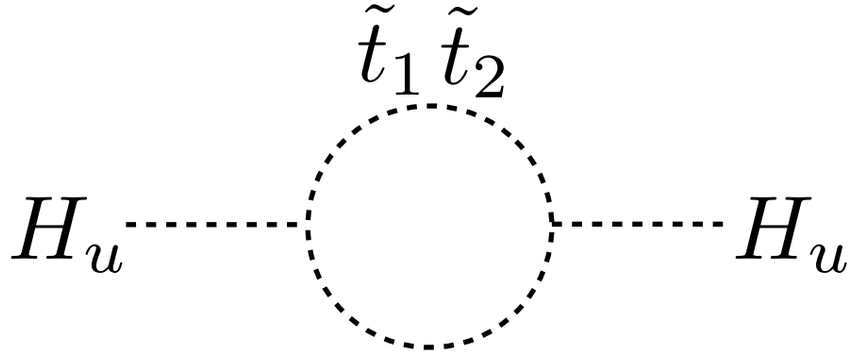




$$\delta m^2_{H_u} \approx -\frac{3y_t^2}{8\pi^2}(m^2_{\tilde{t}_1} + m^2_{\tilde{t}_2} + A_t^2)\,\log\left(\frac{\Lambda}{m_{\tilde{t}}}\right)$$

Light Stops and EW naturalness





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$$\mathrm{v}^2_{\mathrm{EW}} \approx -\frac{c^2_{\mathrm{w}}}{g_2^2}(|\mu|^2 + m^2_{H_u}) = (174\ \mathrm{GeV})^2 \quad (\tan\beta \gg 1)$$

$\Rightarrow$ Stops lighter than ~350 - 700 GeV

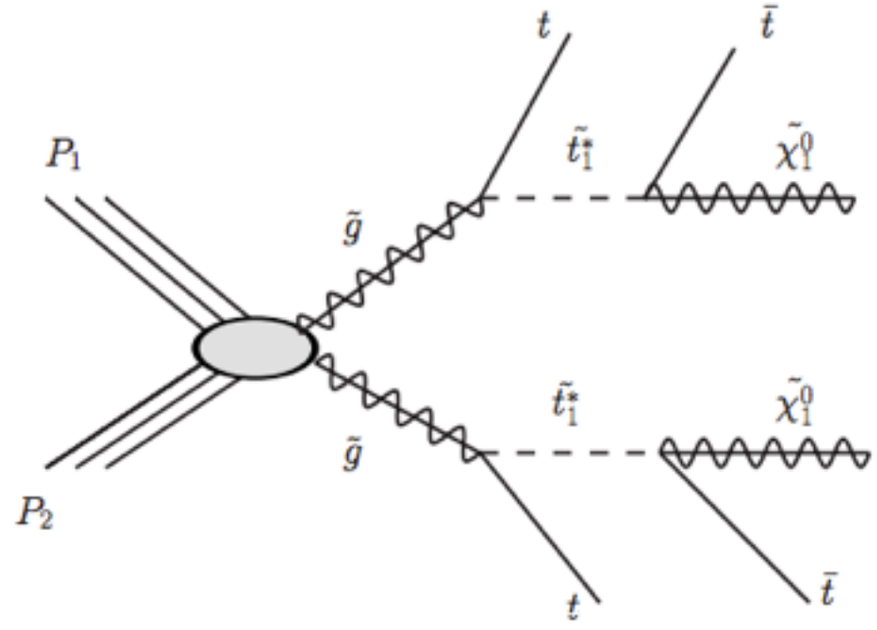
Outline

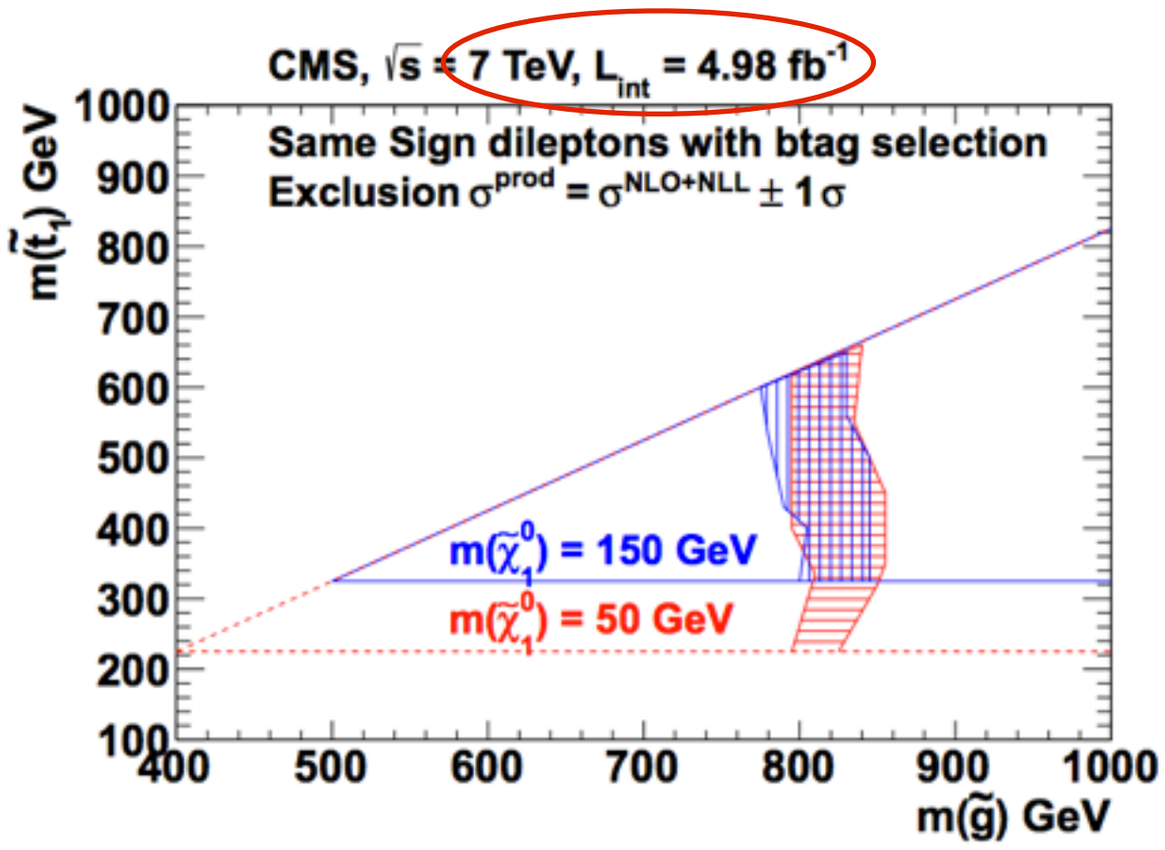
- Updated searches for gluino-mediated stop production
- New searches for direct stop production (ICHEP’12)
- Challenging regions and the need for shape analyses

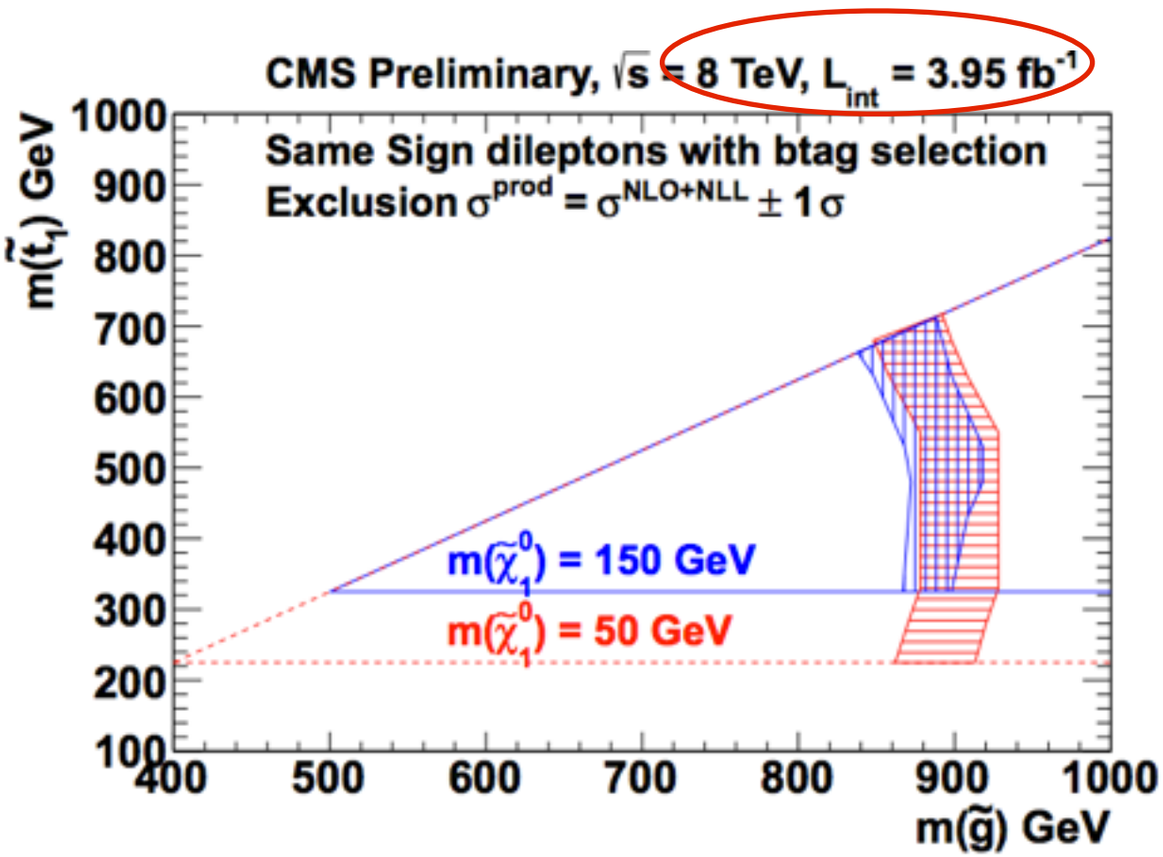
CMS SS dileptons + 2b-jets

CMS PAS SUS-12-017

- 2 same-sign leptons p_T>20 GeV
- 2 b-jets p_T>40 GeV
- Veto on 3rd lepton from Z^0
- 9 MET-H_T signal regions



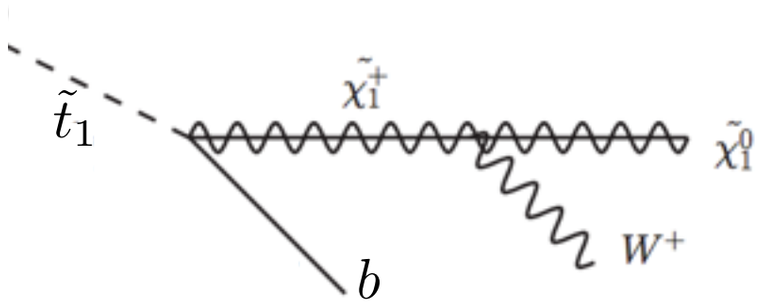


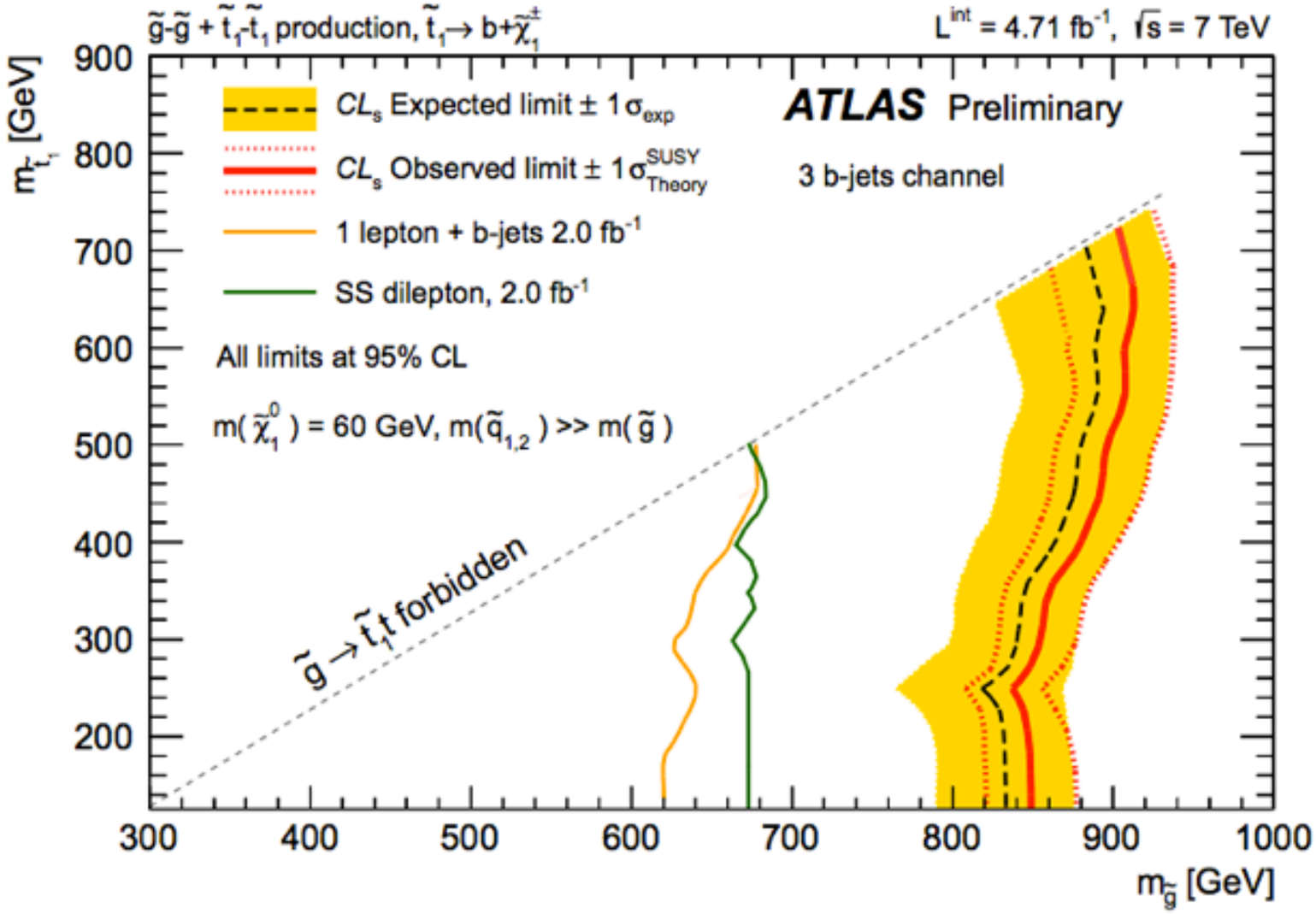


ATLAS all hadronic w/ 3^{+}b-jets

ATLAS-CONF-2012-058

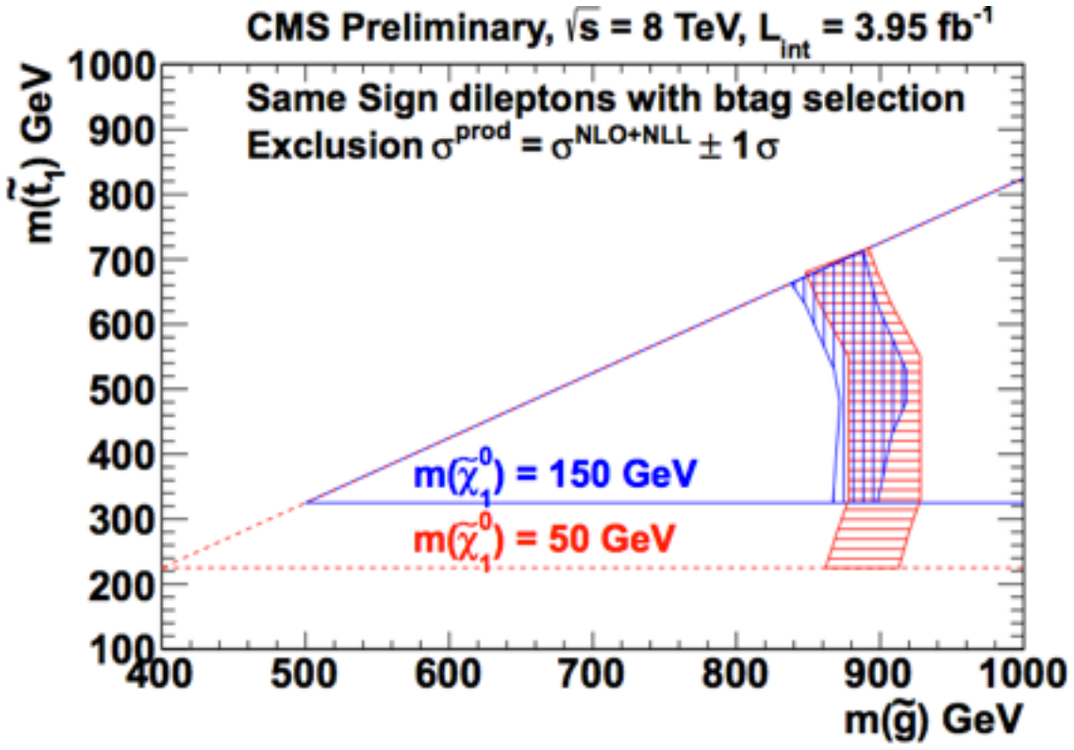
Veto on isolated leptons
≥4 (6) jets with p_T>50 GeV
≥3 b-jets
MET>160-200 GeV
m_{eff}>500-900 GeV

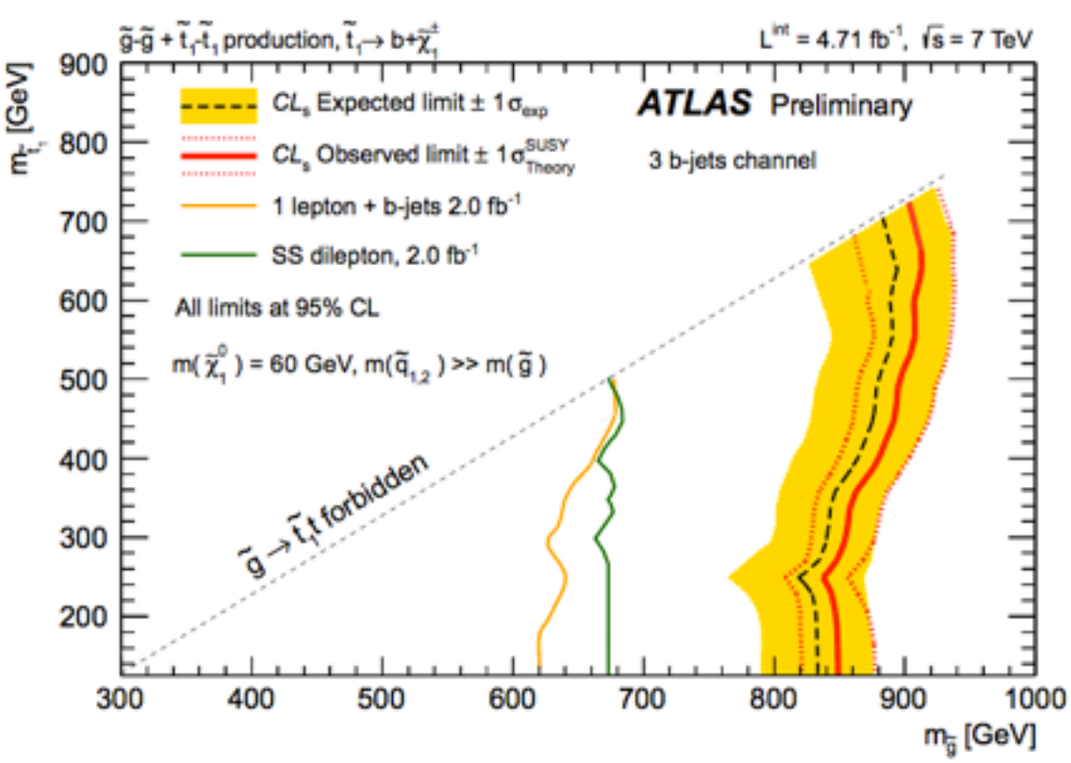




So long as $m_{\tilde{g}} \lesssim 900$ GeV and spectrum is not compressed

- Strong constraint on stops $\Rightarrow m_{\tilde{t}} \gtrsim 700$ GeV





ICHEP 2012

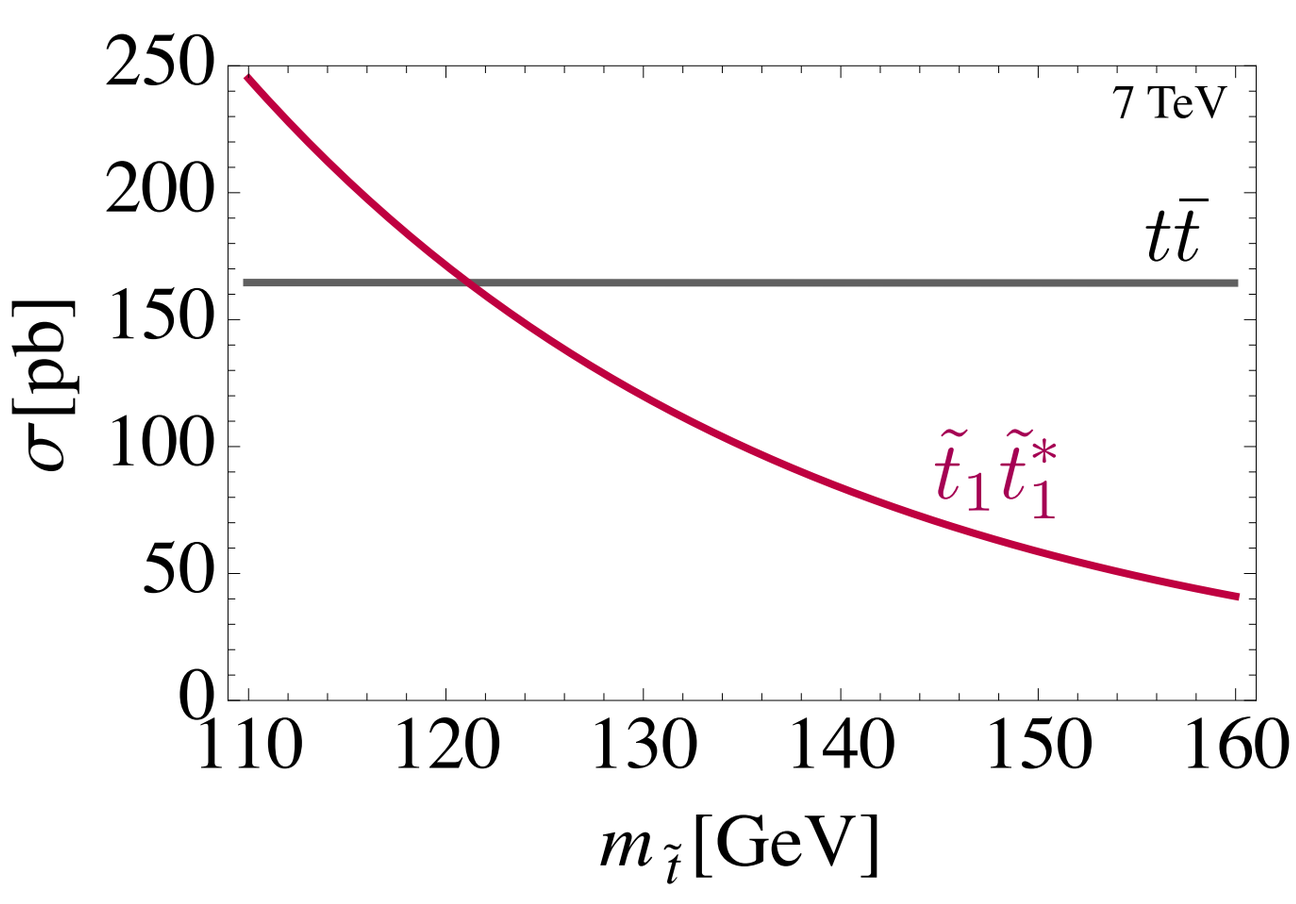
First results on direct stop production

ATLAS search for stops lighter than top

ATLAS-CONF-2012-059

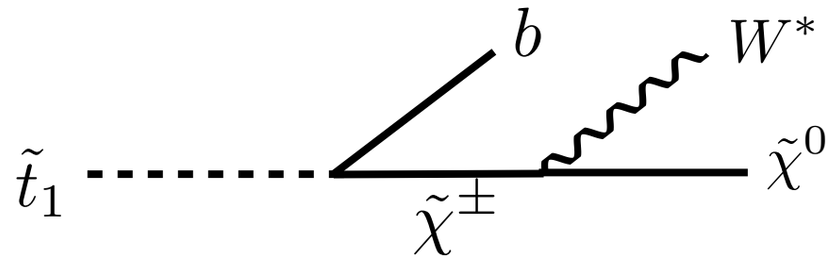
2 leptons + MET + ≥ 1 jet

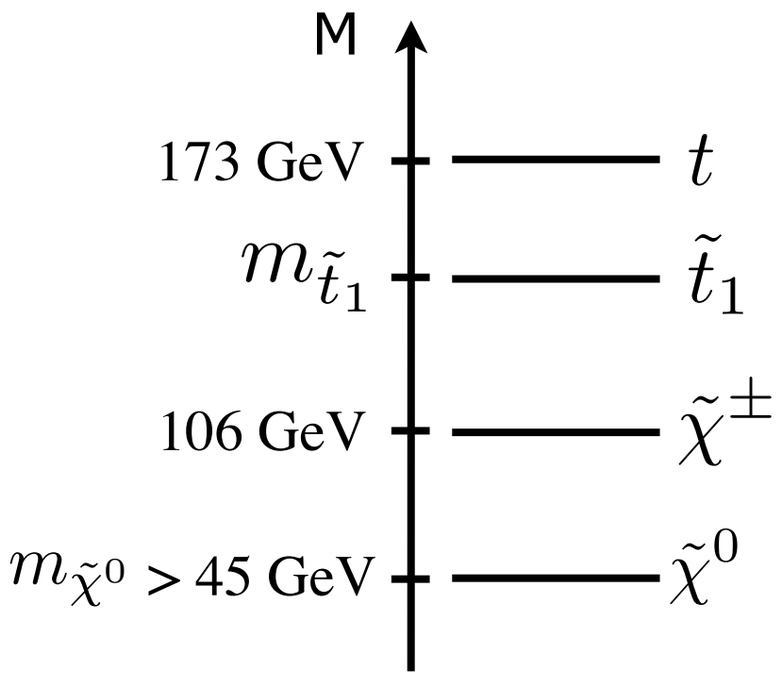
$$p_{T1}^{\ell} < 30 \text{ GeV}$$

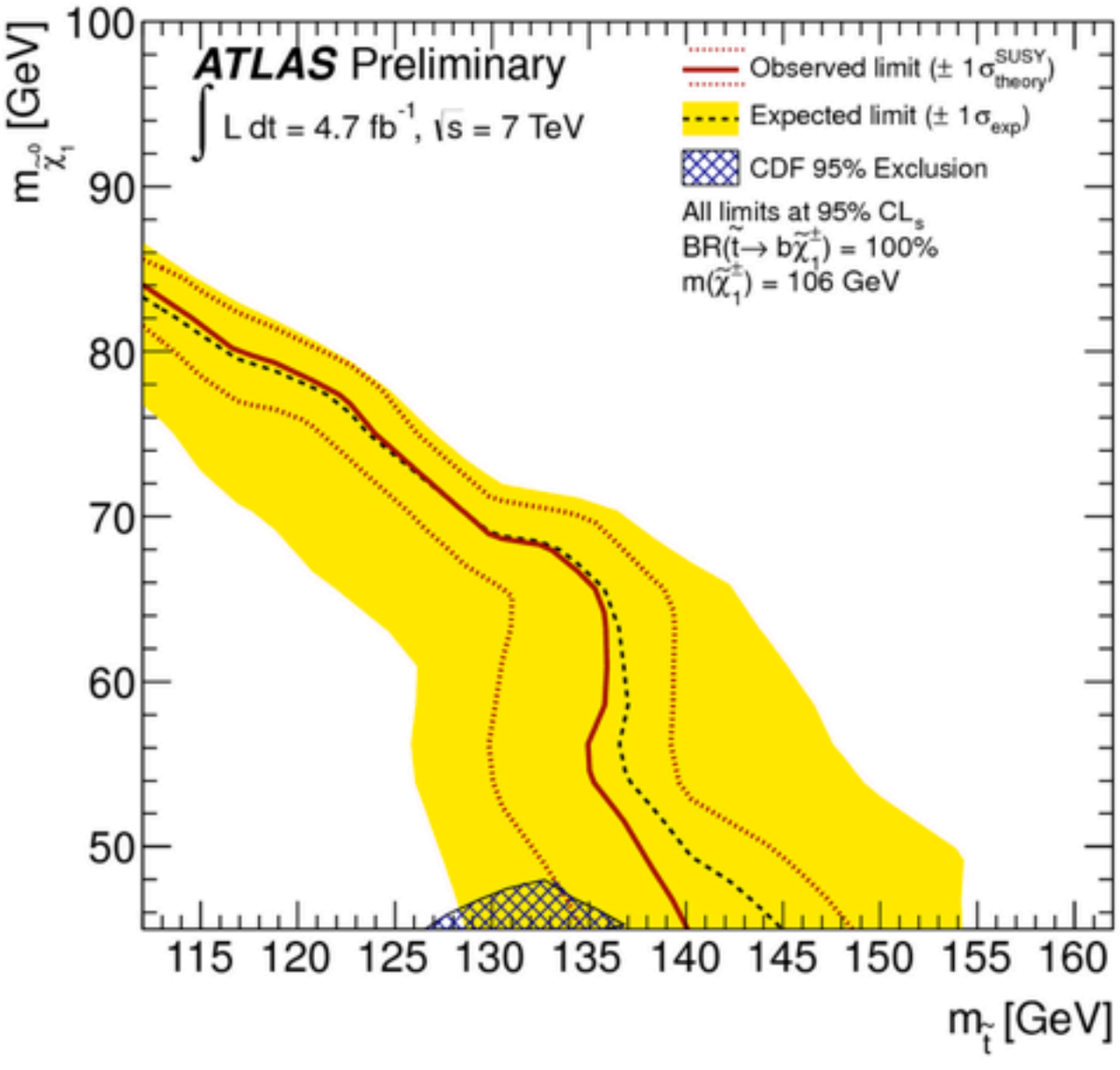


ATLAS search for stops lighter than top

ATLAS-CONF-2012-059







ATLAS search for stops *lighter or close* to top

ATLAS-CONF-2012-070

exclusive 1 or 2 leptons

MET > 40 GeV

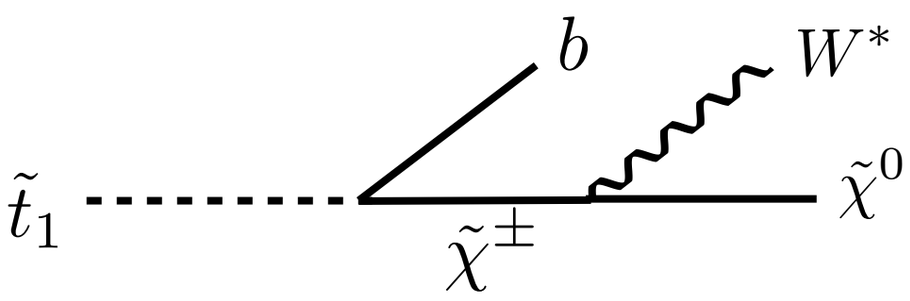
M_T > 30 GeV (1 lep)

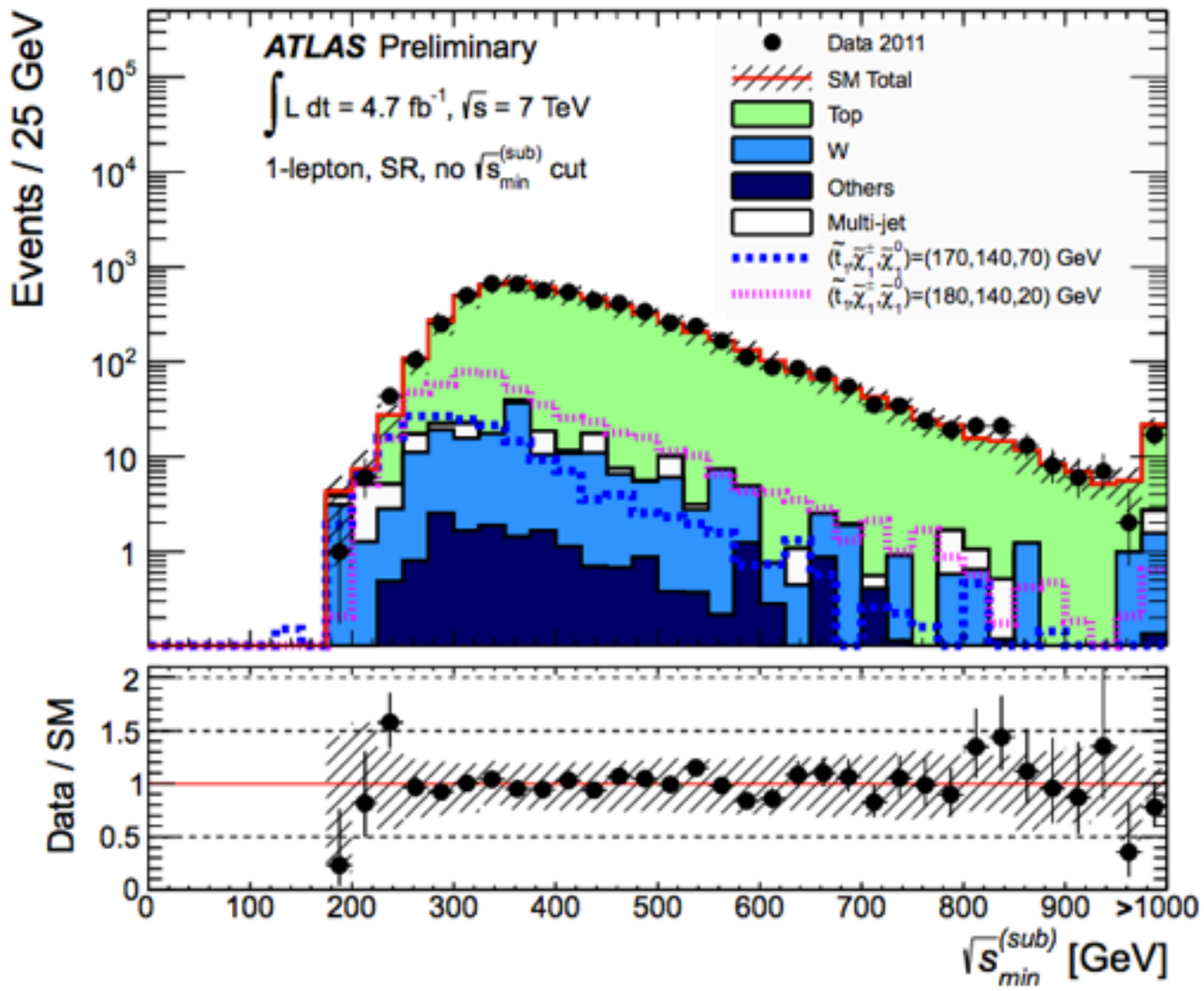
top mass window (1 lep)

30 < m_{ll} < 81 GeV (2 lep)

new variable: $\sqrt{s}_{min}^{(sub)}$

intended to capture mass scale of stop pair production (ISR subtracted)





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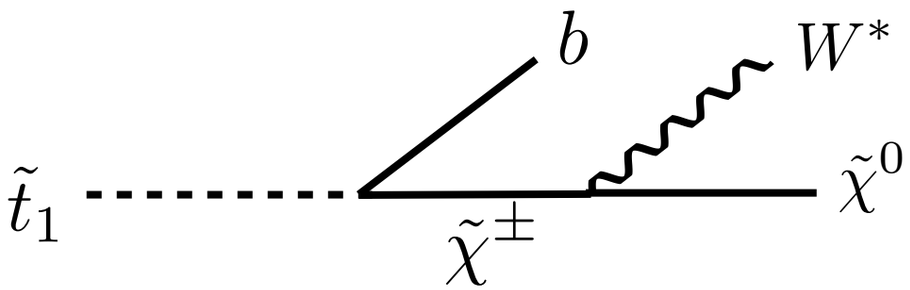

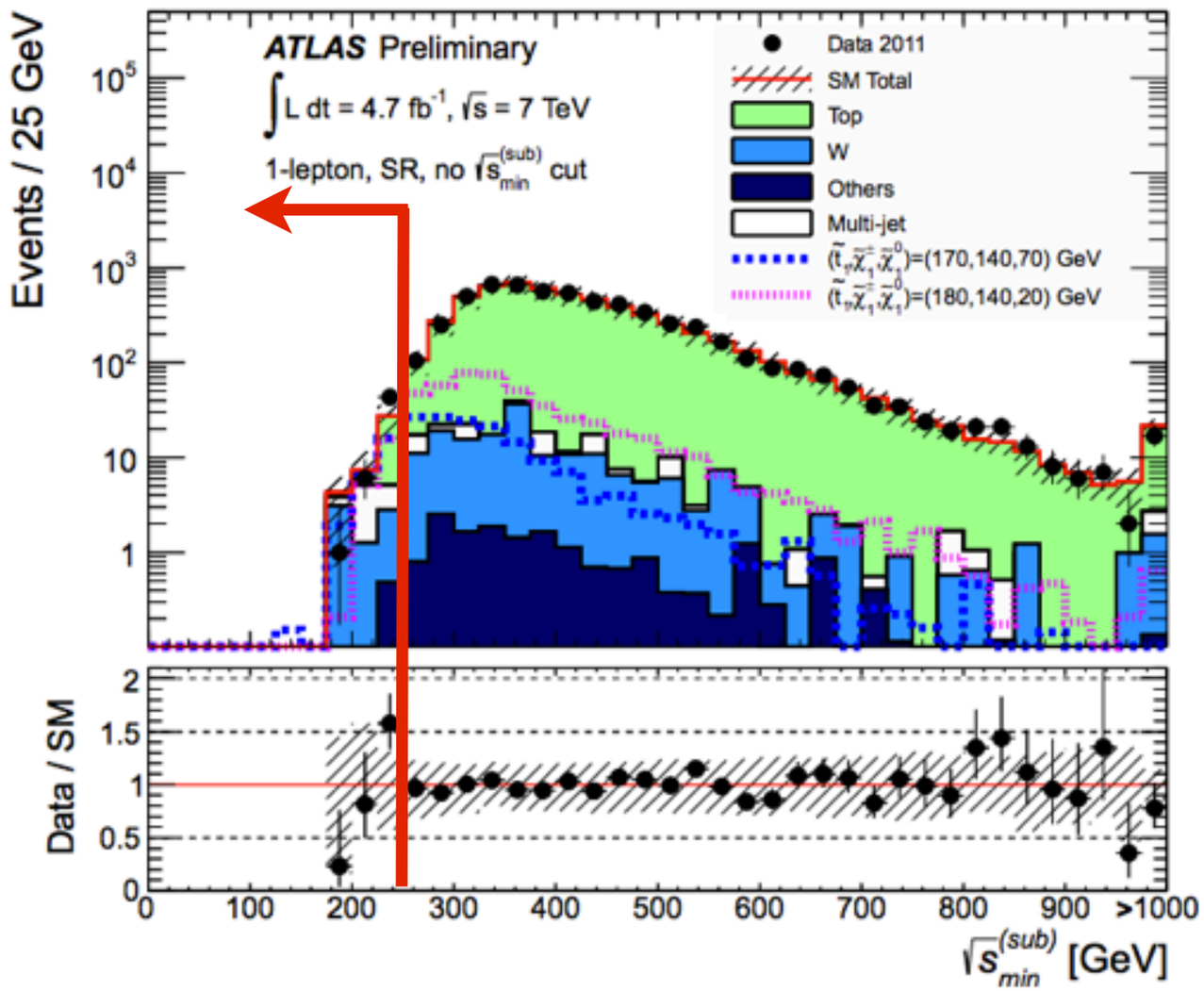

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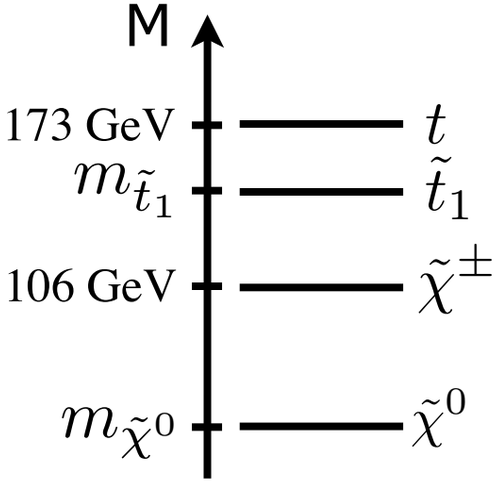
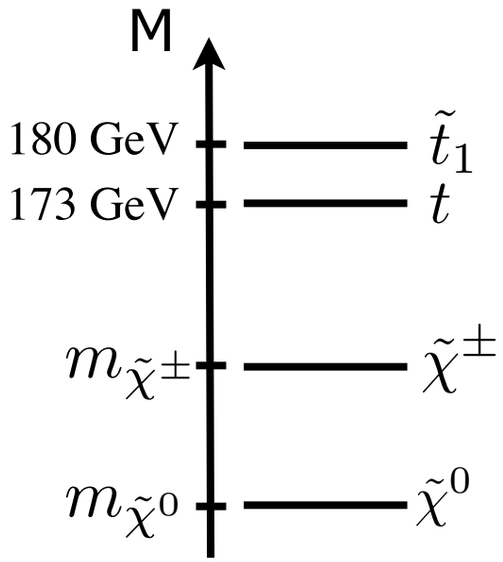
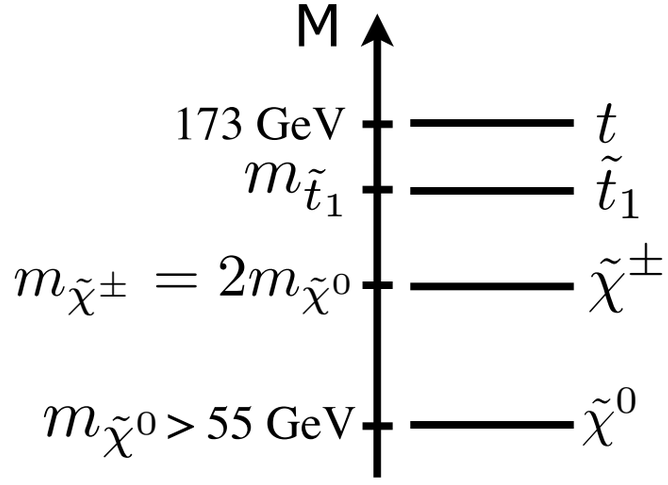
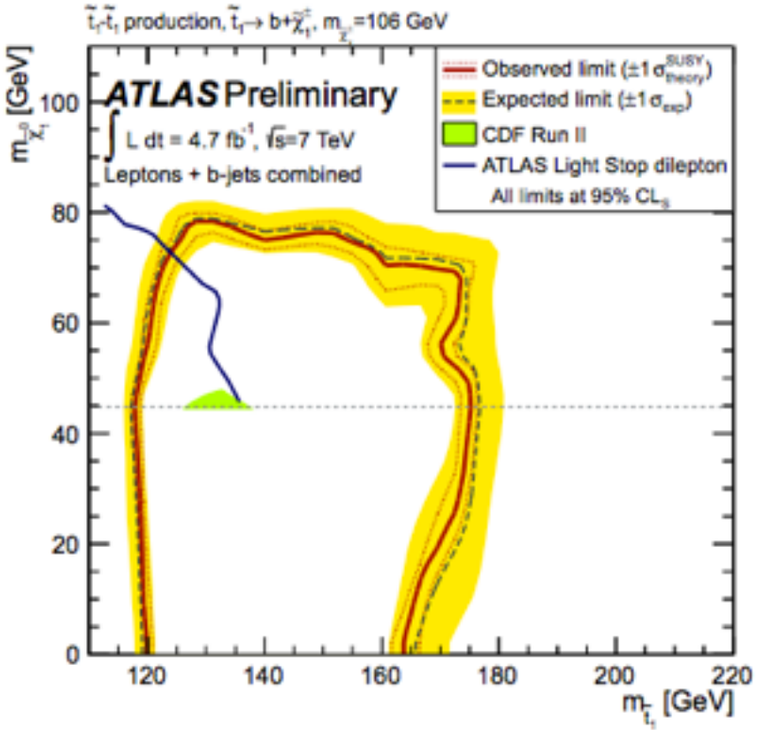
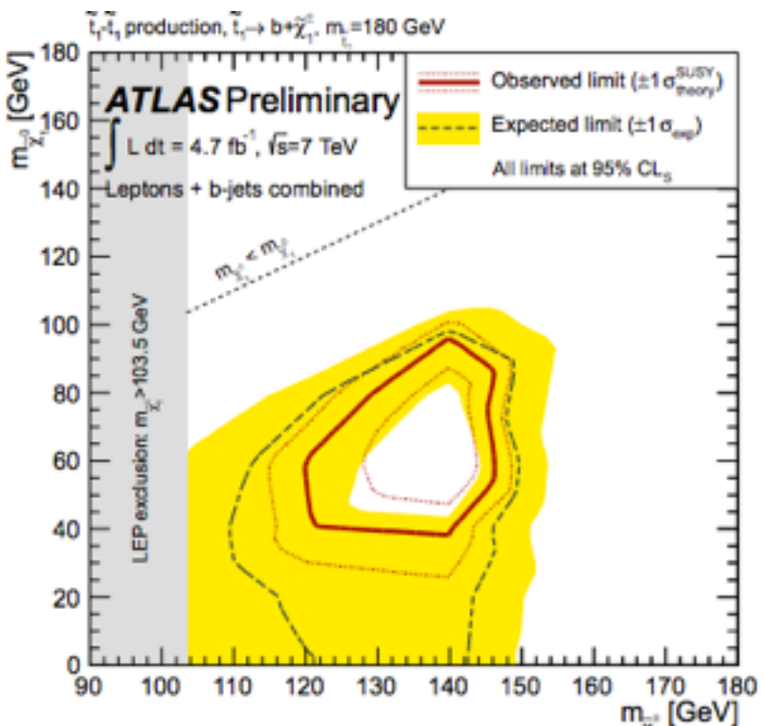
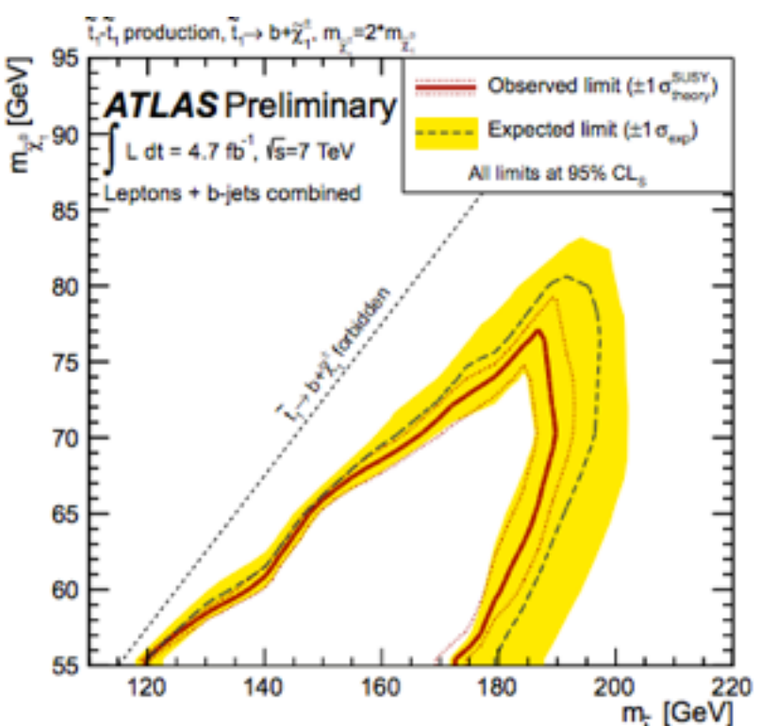












ATLAS search in dileptons

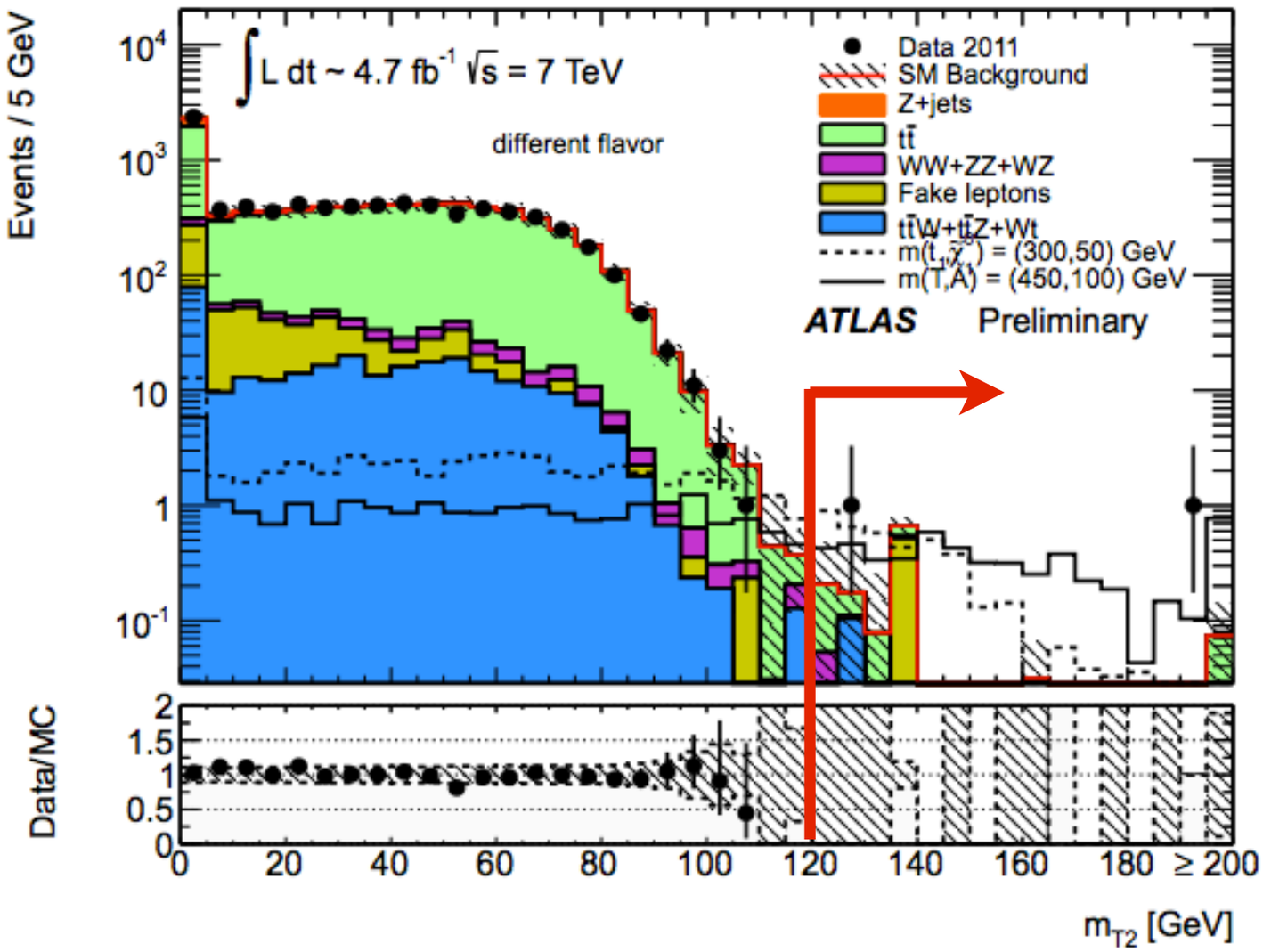
ATLAS-CONF-2012-071

exclusive 2 leptons (Z^0 veto)

2 jets $p_{T1,2}$> 50, 25 GeV

≥1 b-tag

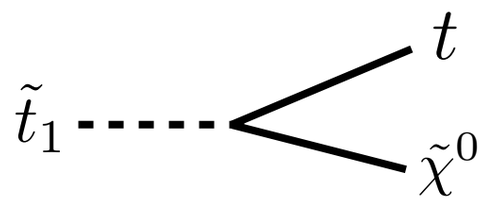
m_{T2} > 120 GeV

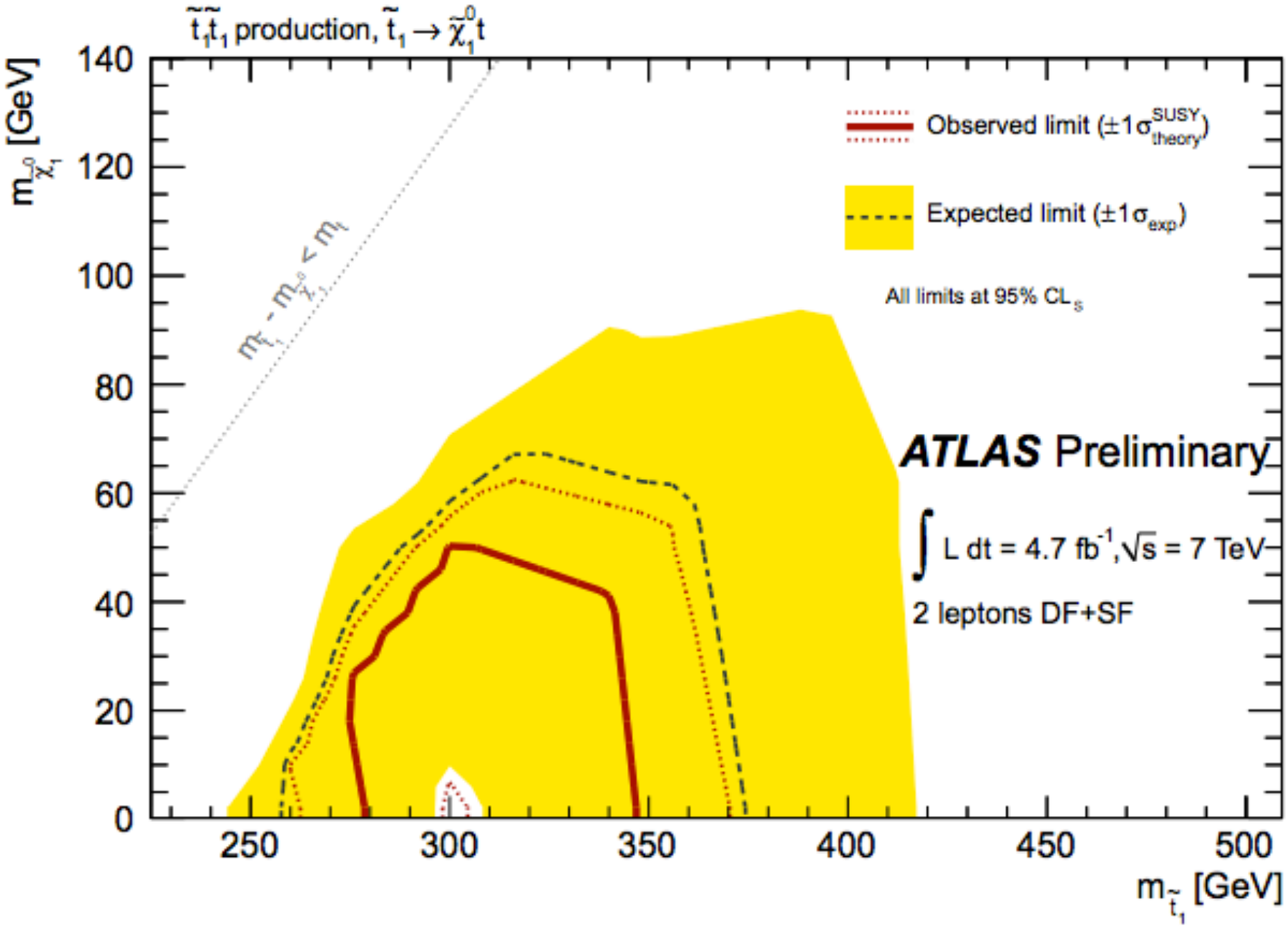


	SF	DF
Total SM	1.6 ± 0.6	0.9 ± 0.6
Signal, m($\tilde{t}_1$) = 300 GeV, m($\tilde{\chi}_1^0$)= 50 GeV	2.15	3.73
Signal, m(T) = 450 GeV, m(A_0)= 100 GeV	3.10	5.78
Observed	1	2
95% CL limit on σ_{vis}^{obs}[fb]	0.86	1.08
95% CL limit on σ_{vis}^{exp}[fb]	0.89	0.79

ATLAS search in dileptons

ATLAS-CONF-2012-071





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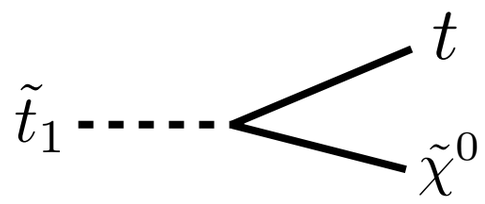
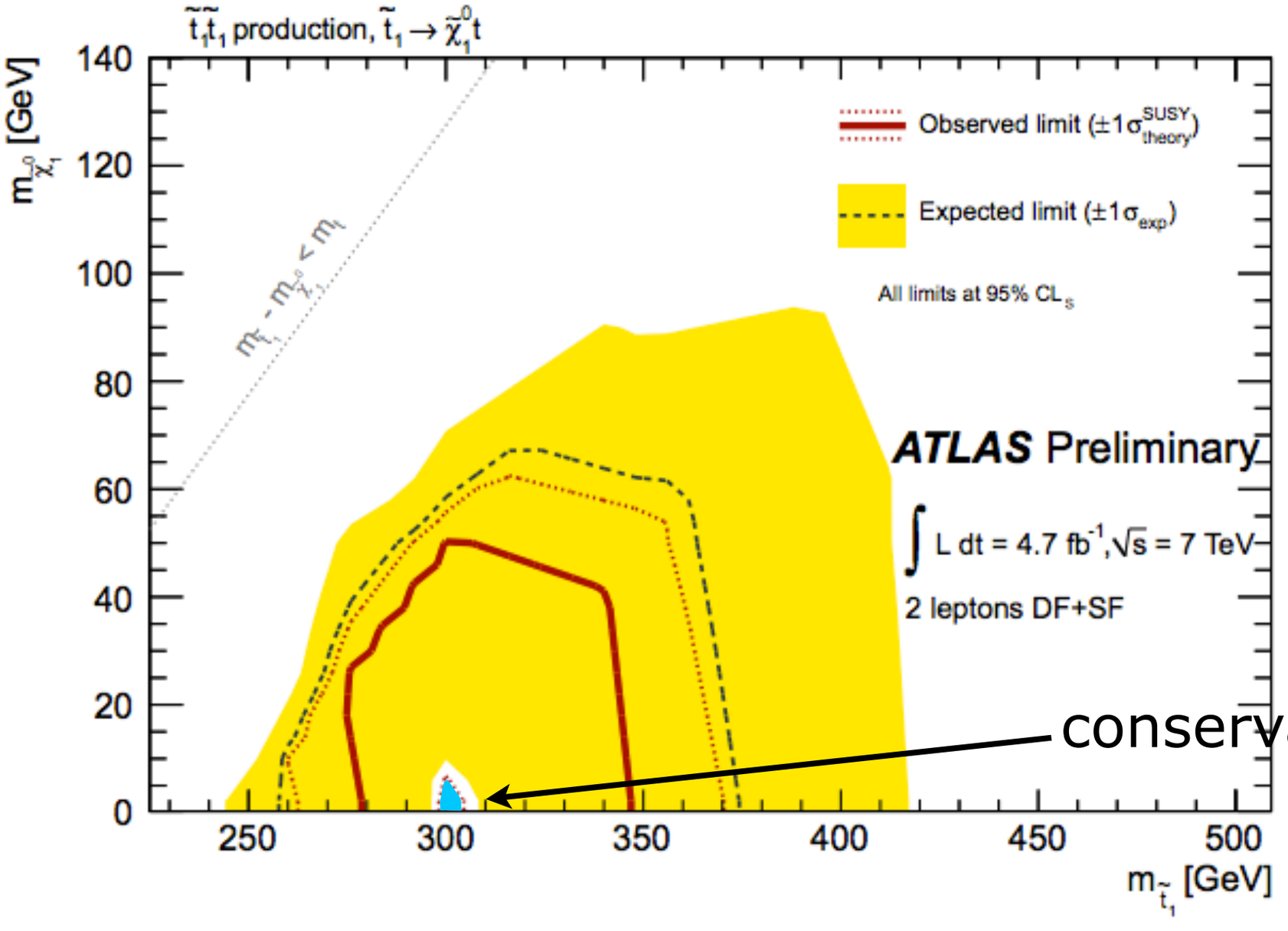




ATLAS hadronic search

ATLAS-CONF-2012-074

6 jets p_T > 30 GeV (p_{T1}> 130 GeV)

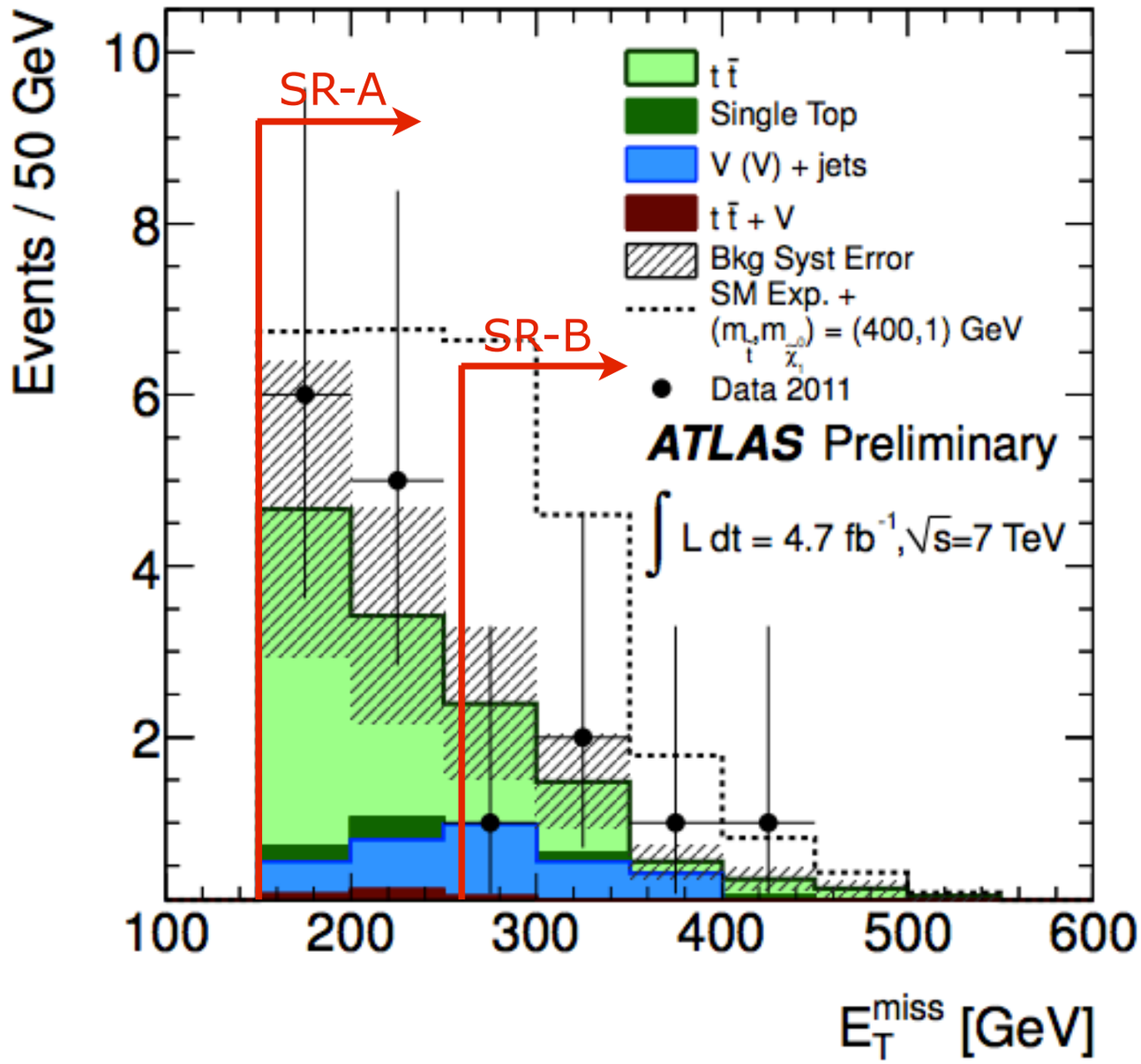
lepton veto

≥1 tight b-tag or ≥2 loose b-tags

80 < m_{jjj} < 270 GeV

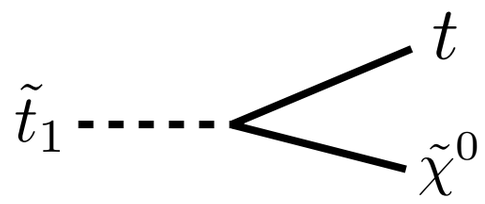
m_T (b, MET) < 175 GeV

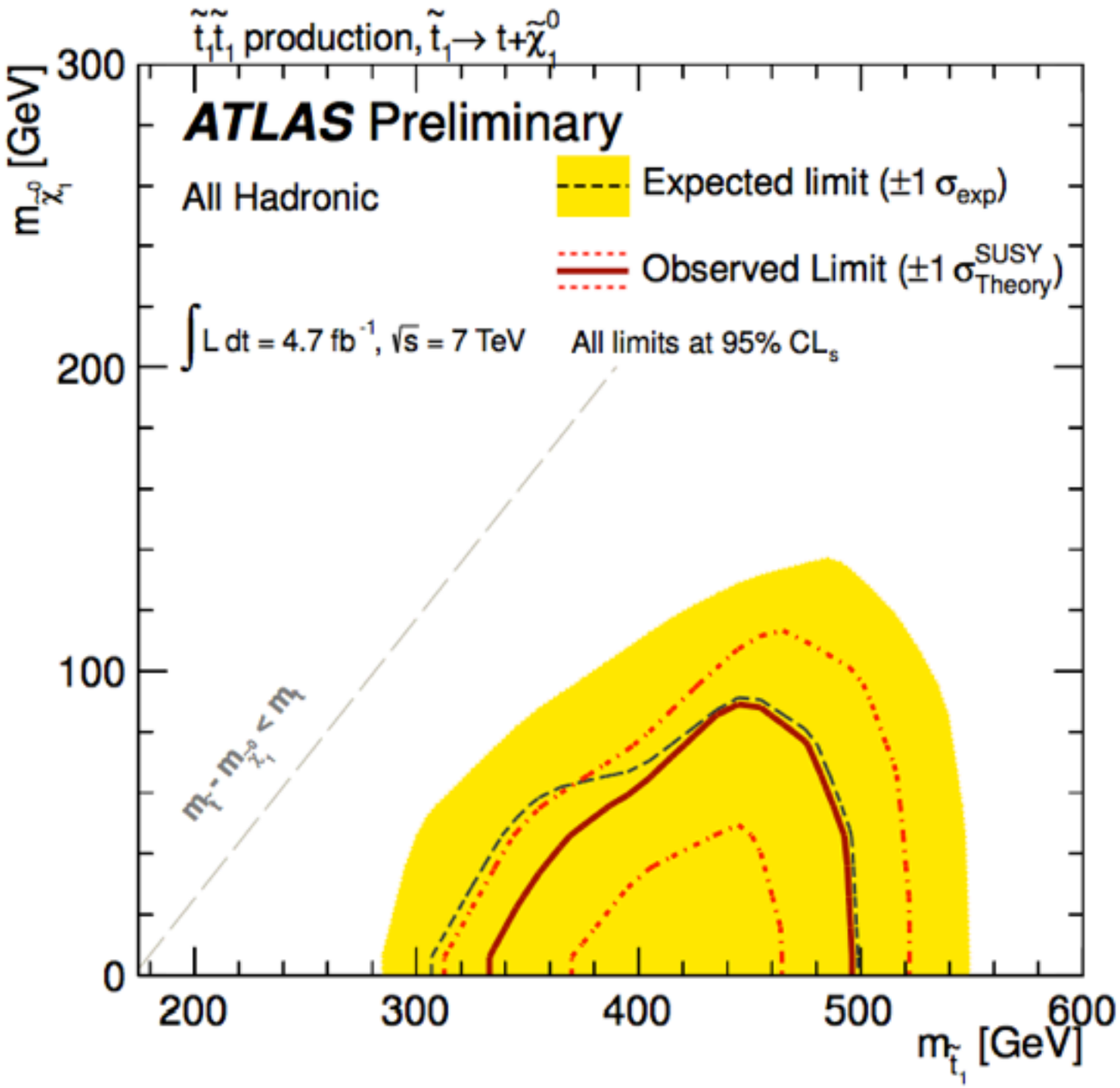
veto on τ_{had} : jets w/ 1-4 tracks; $\Delta\varphi$(j,MET)<π/5; m_T < 100 GeV



ATLAS hadronic search

ATLAS-CONF-2012-074





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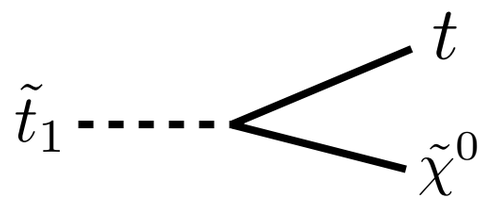
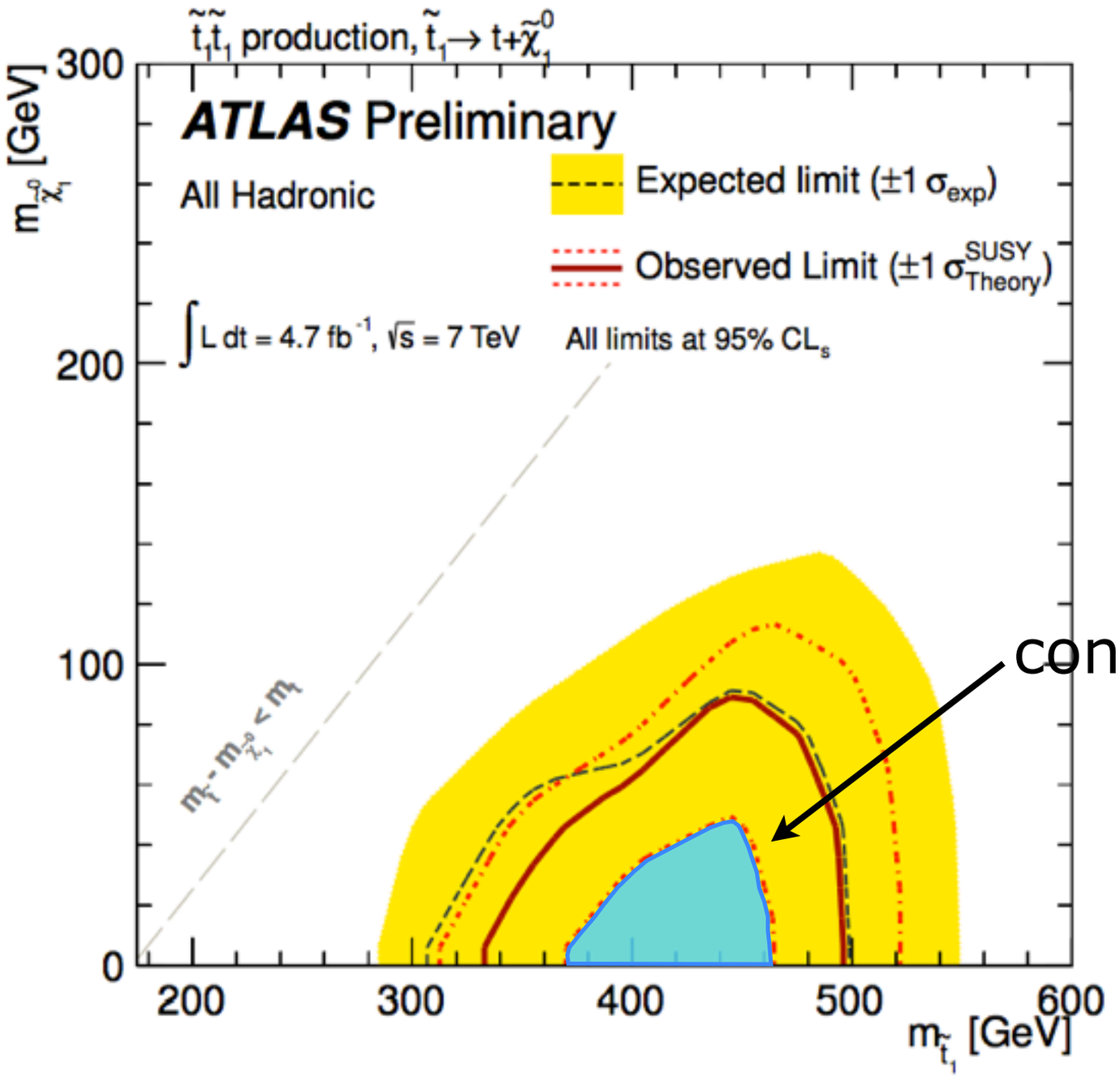




conservative limit

ATLAS semi-leptonic search

ATLAS-CONF-2012-073

1 lepton $p_{T\mu(e)} > 20(25)$ GeV

4 jets $p_{T1,2,3,4} > 80, 60, 40, 25$ GeV

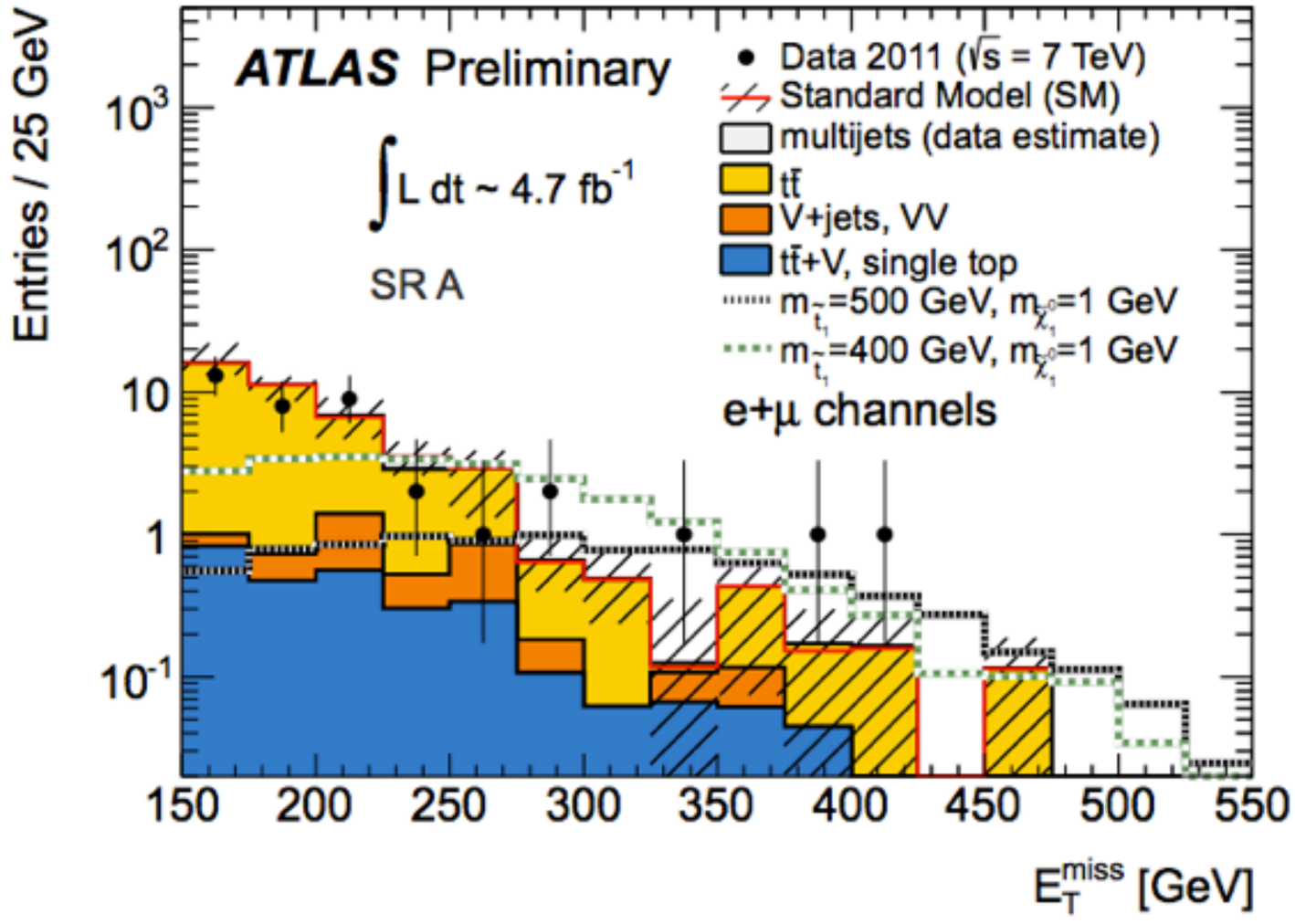
≥1 b-jet

$m_{jj} > 60$ GeV

$130 < m_{jjj} < 205$ GeV

$m_T > 120\text{-}140$ GeV

MET > 150-275 GeV



ATLAS semi-leptonic search

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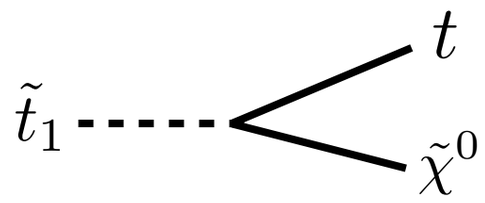

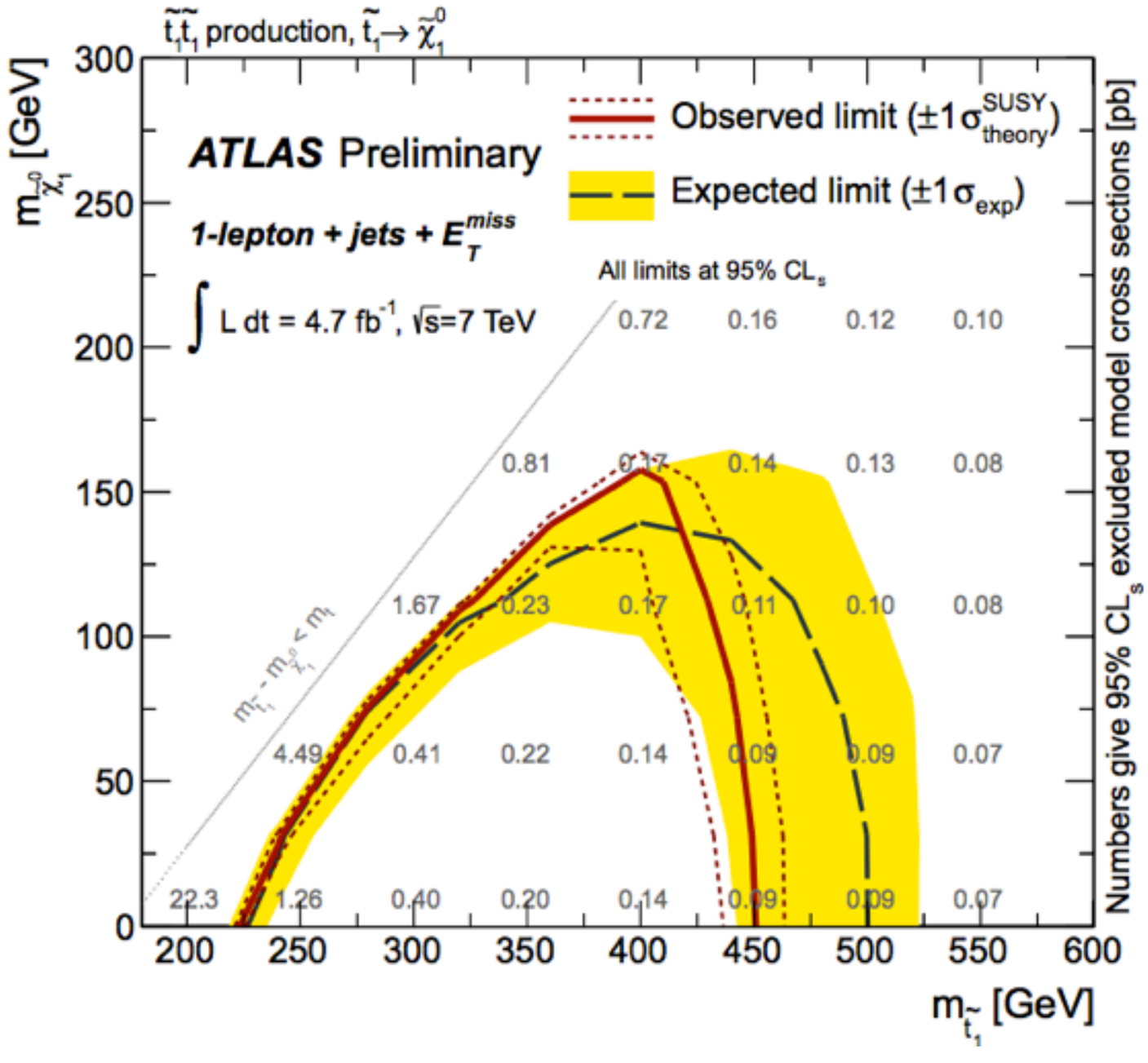

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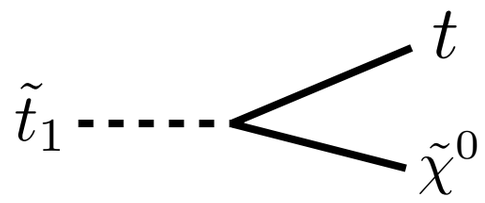
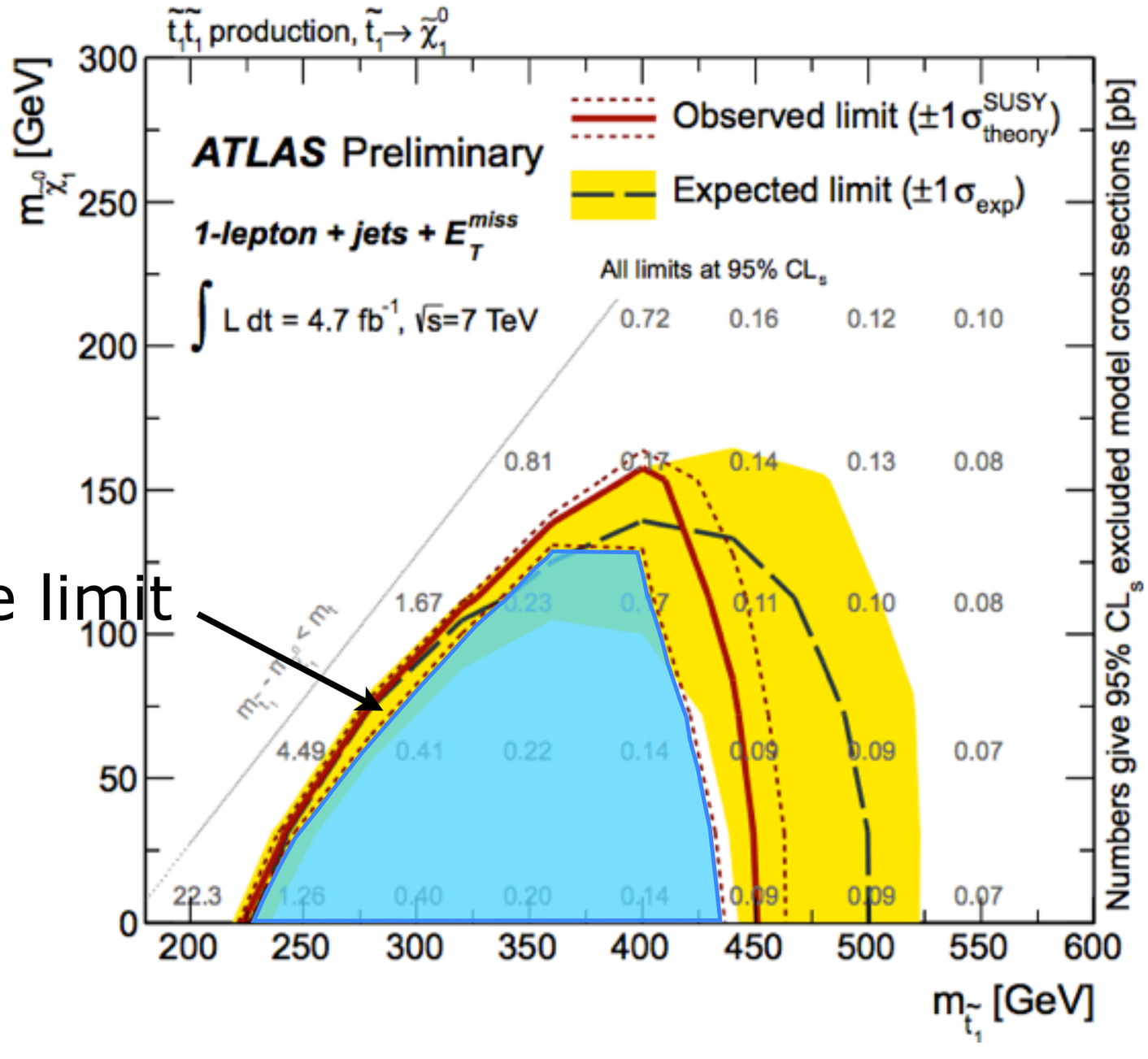
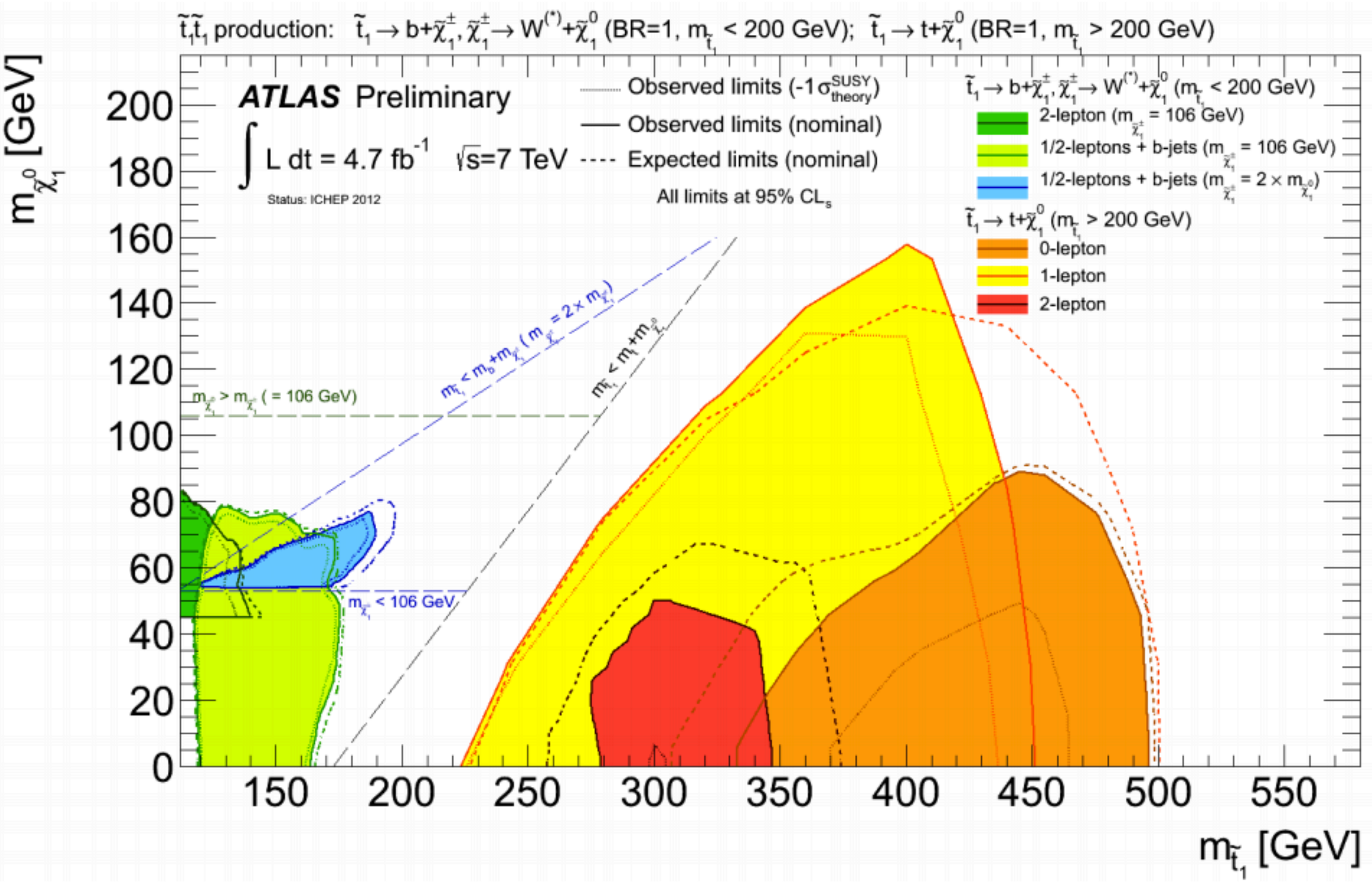
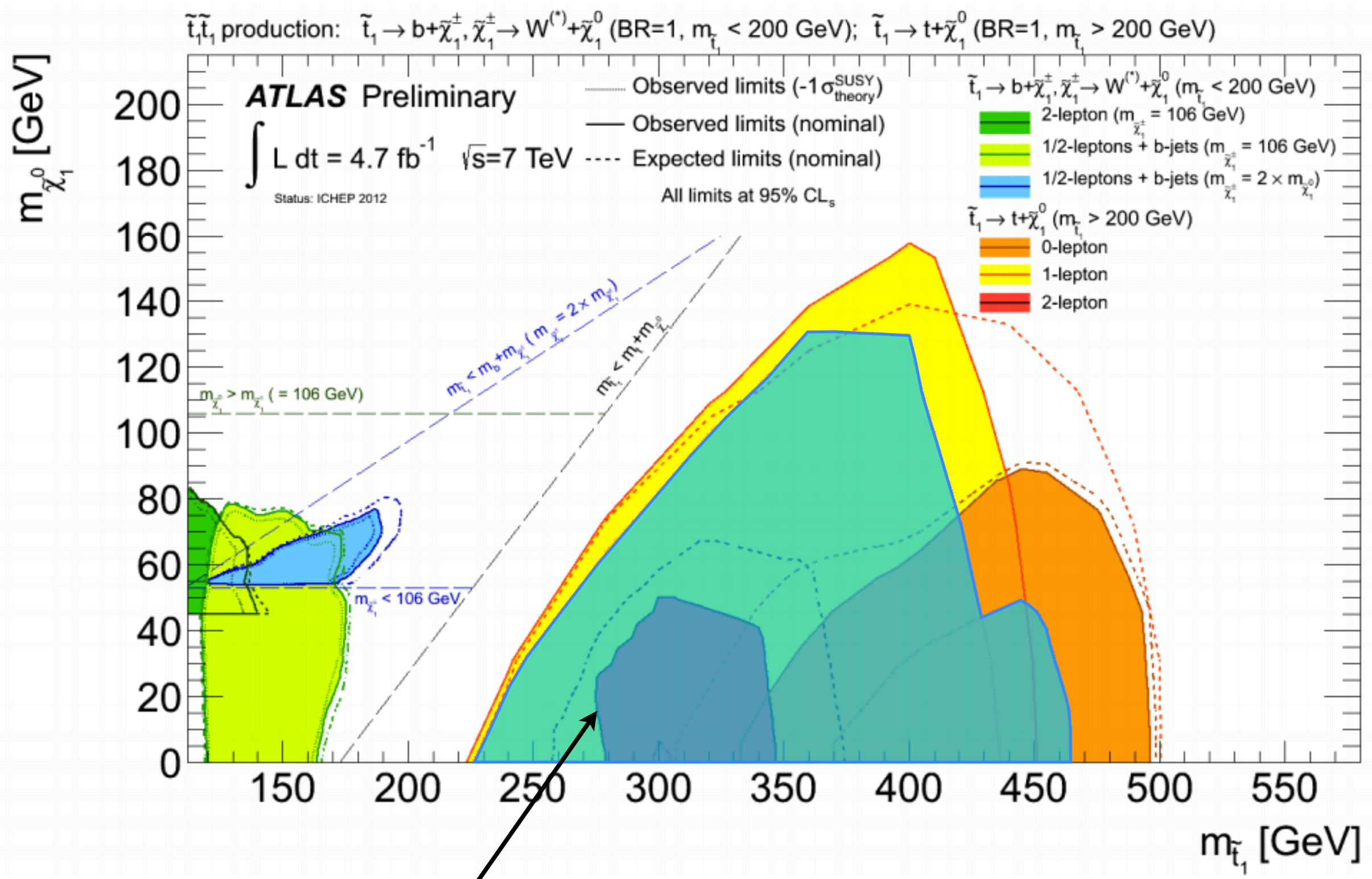


conservative limit





M. White's talk, ICHEP'12



conservative limit

M. White's talk, ICHEP'12

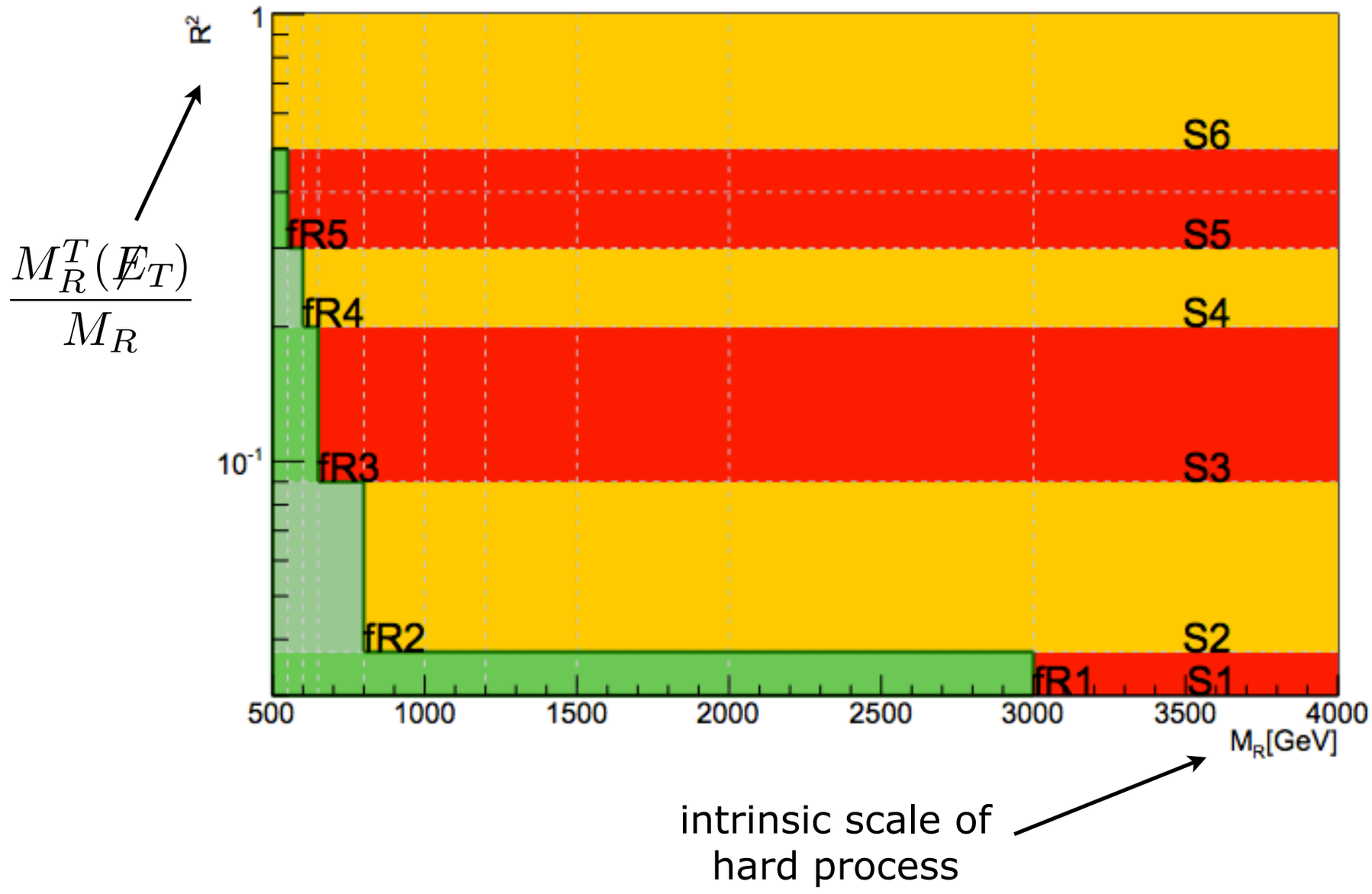
CMS razor multijet

CMS PAS SUS-12-009

6 jets p_T > 30 GeV (p_{T1}> 80 GeV)

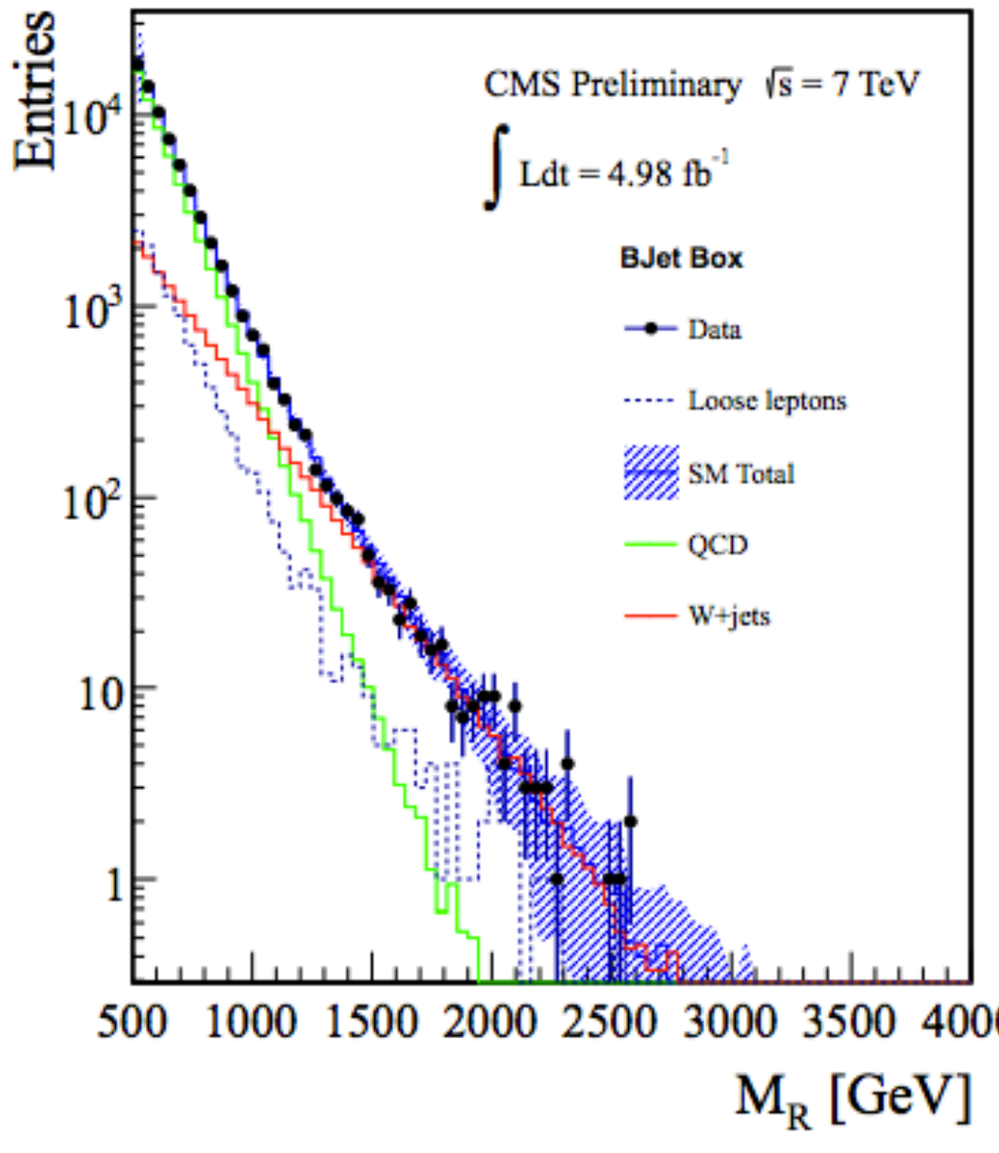
≥1 medium b-tag

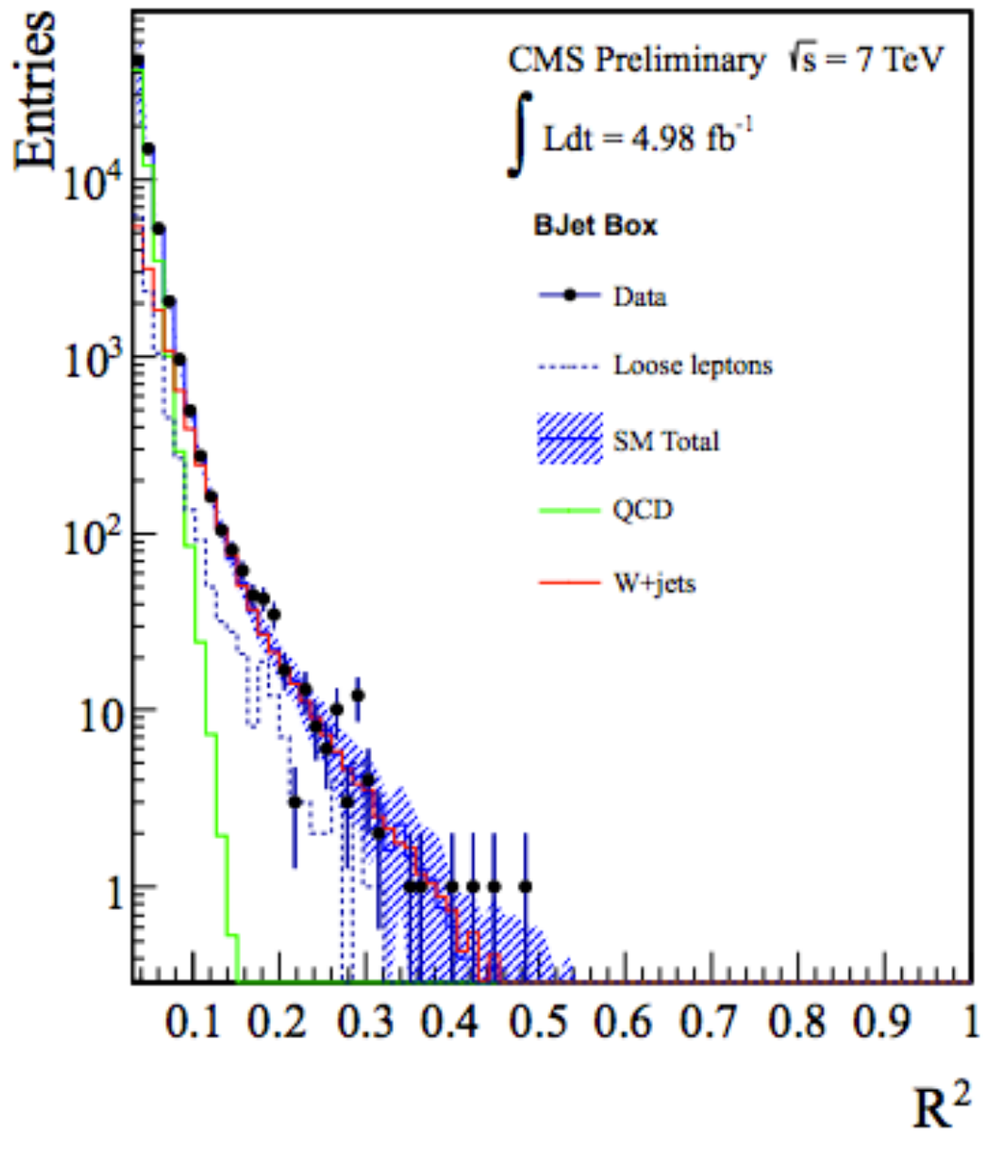
lepton veto



CMS razor multijet

CMS PAS SUS-12-009





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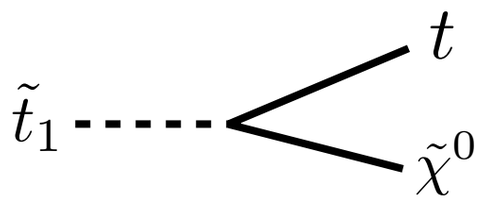
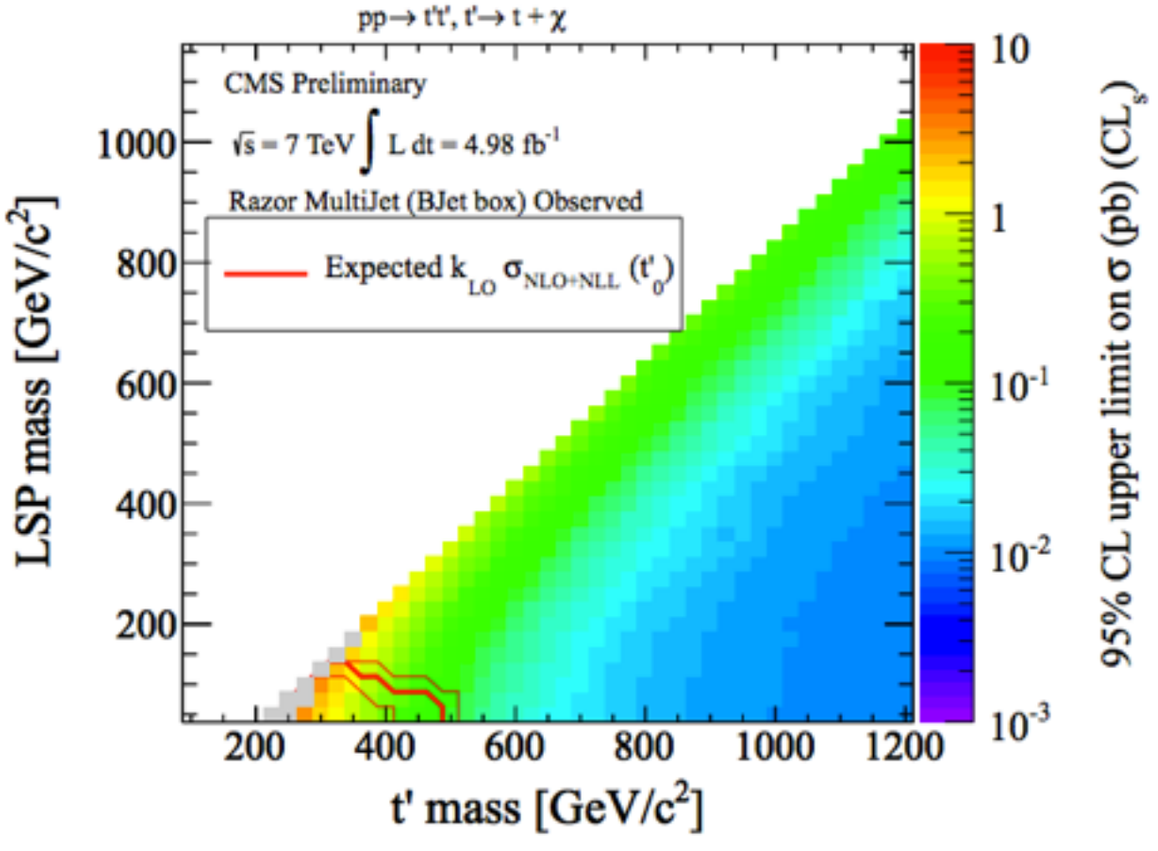
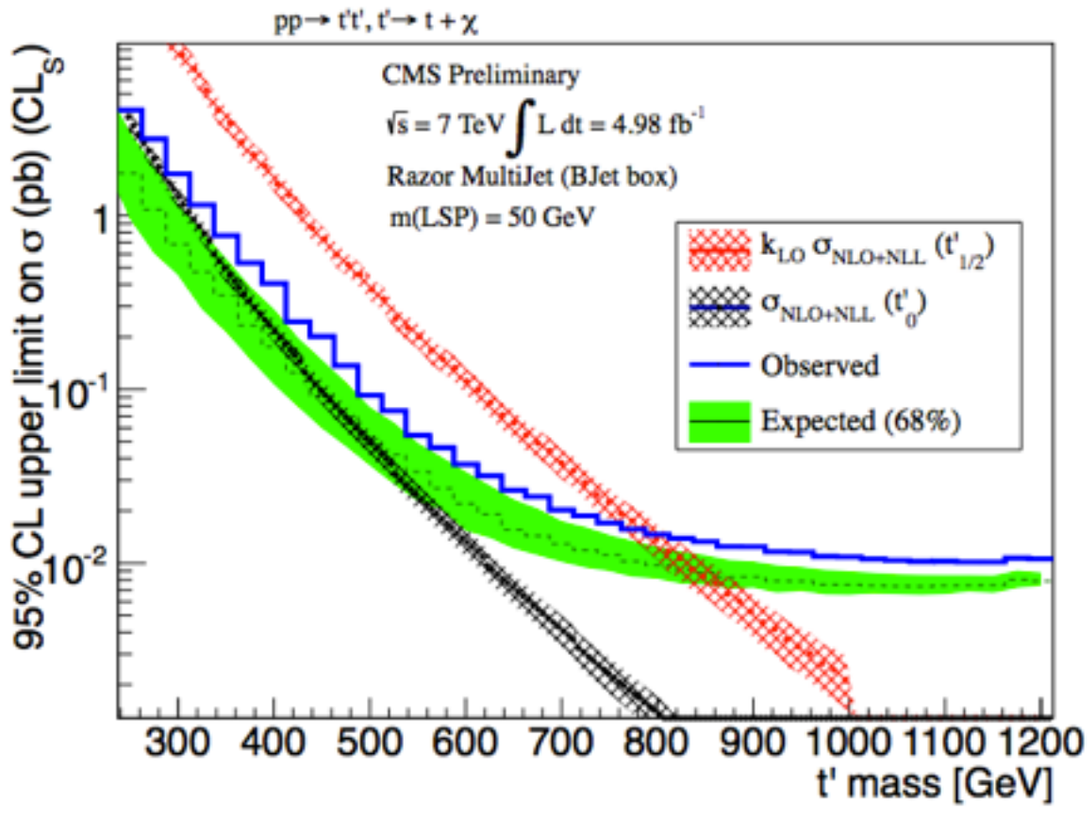


No limits!



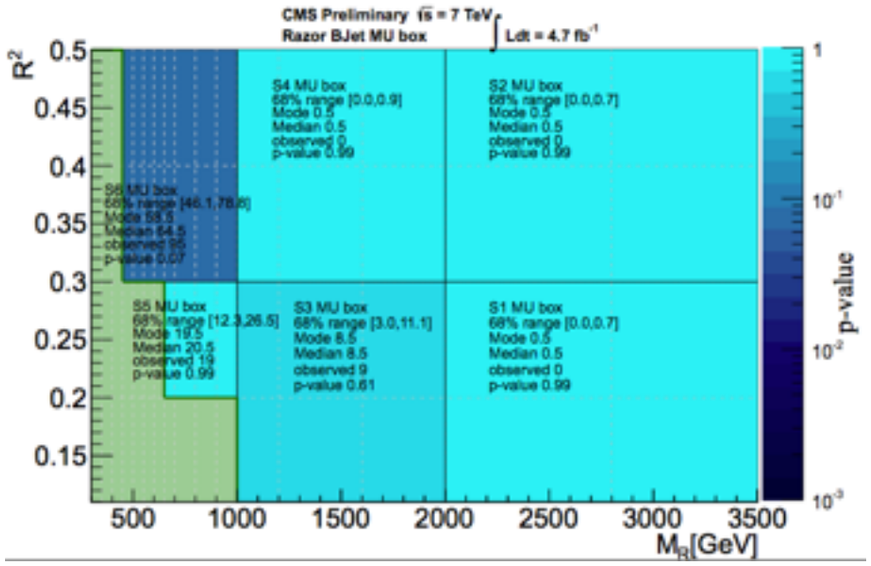


CMS razor b-jet inclusive

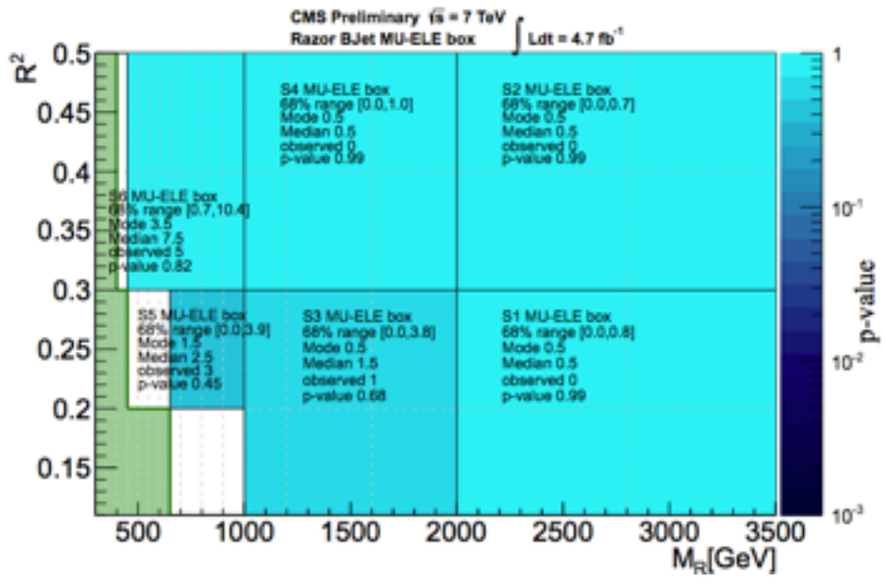
CMS PAS SUS-12-009

2 jets p_T > 60 GeV

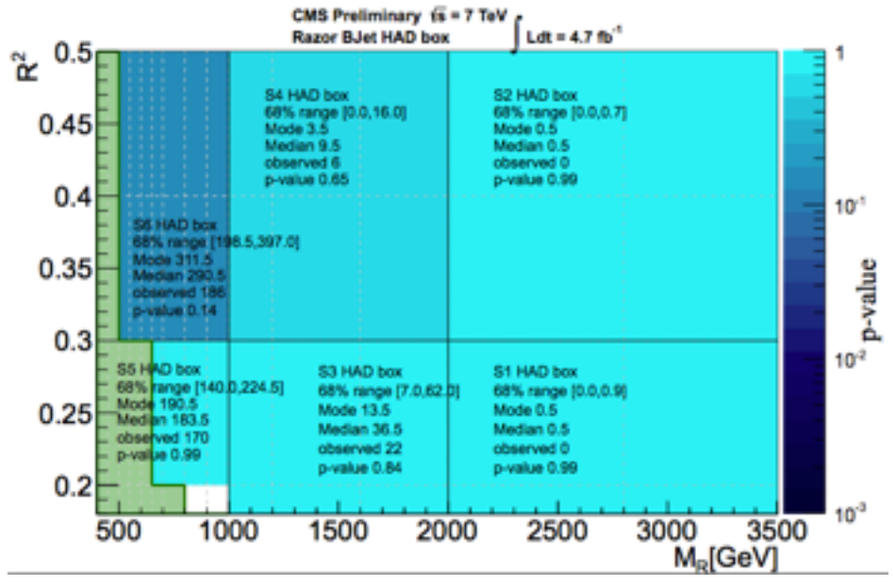
≥1 medium b-tag, p_T > 40 GeV



semileptonic box



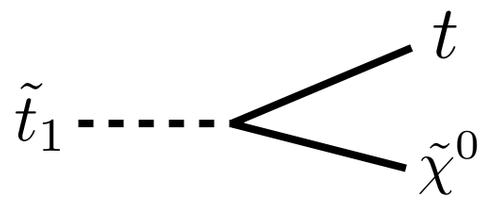
dileptonic box

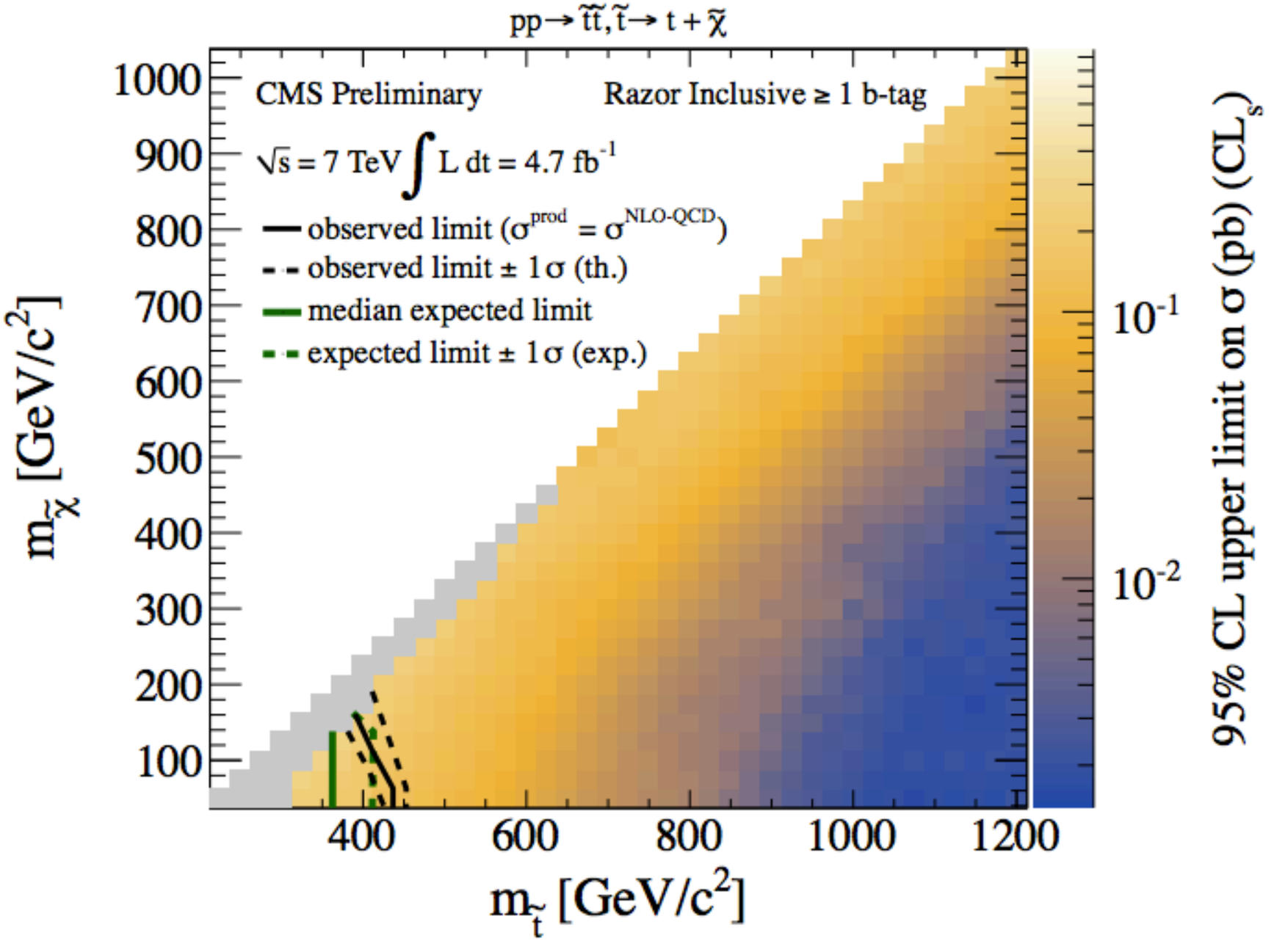


hadronic box

CMS razor b-jet inclusive

CMS PAS SUS-12-009





CMS razor b-jet inclusive

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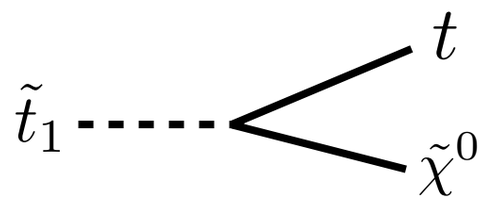
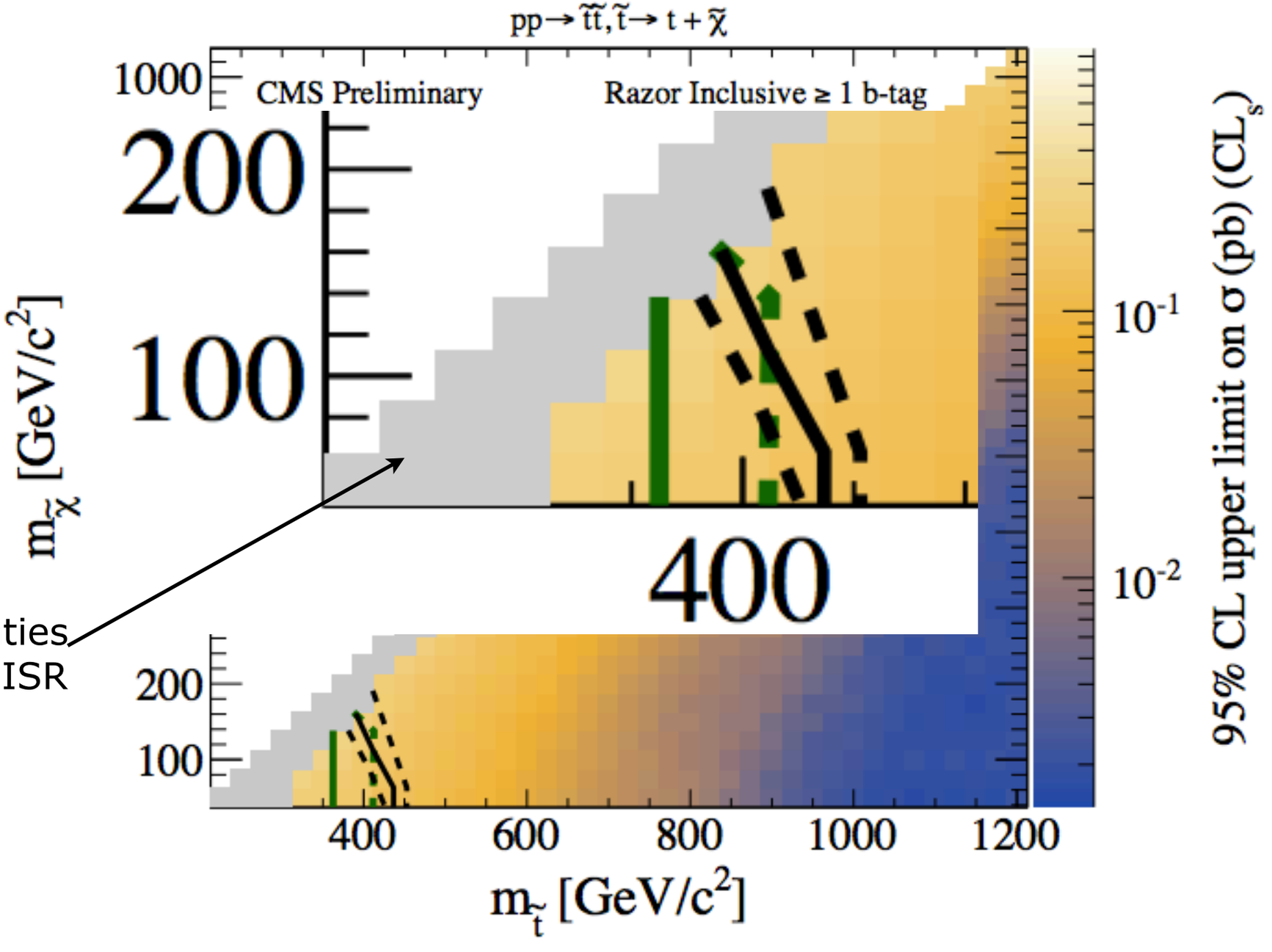
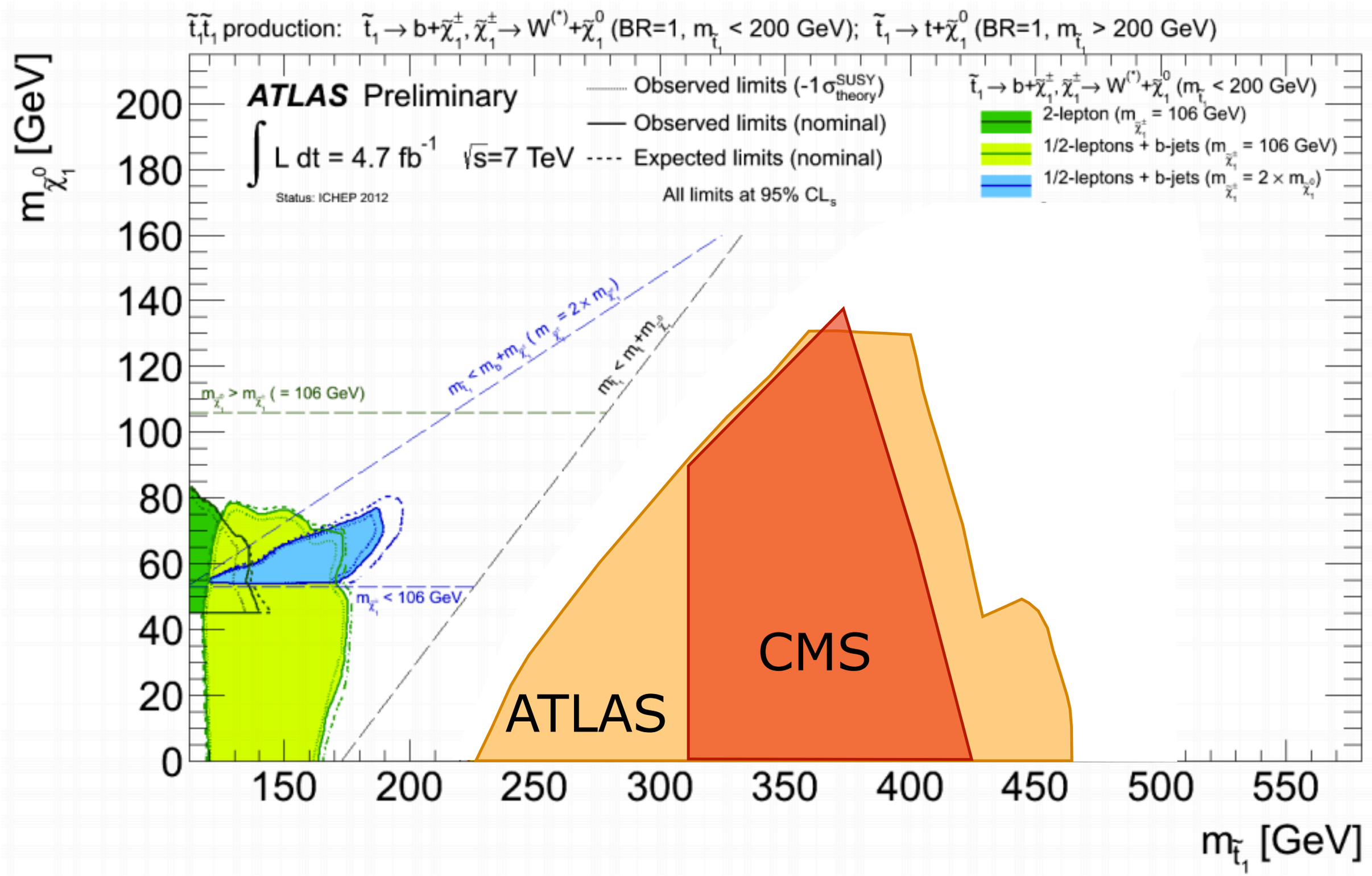


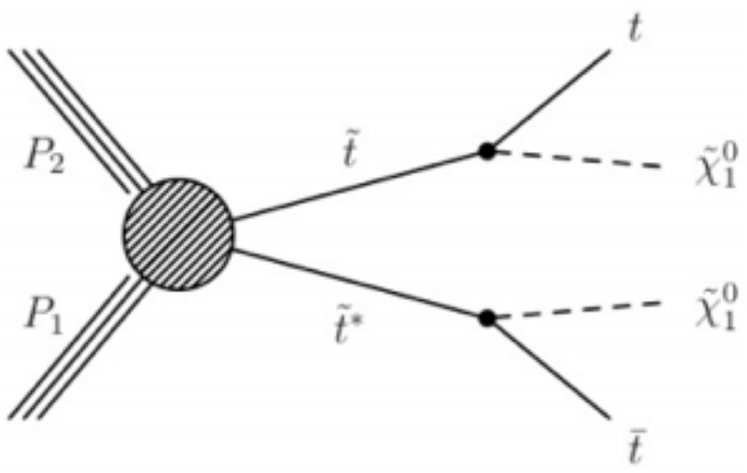


large uncertainties
in modeling of ISR

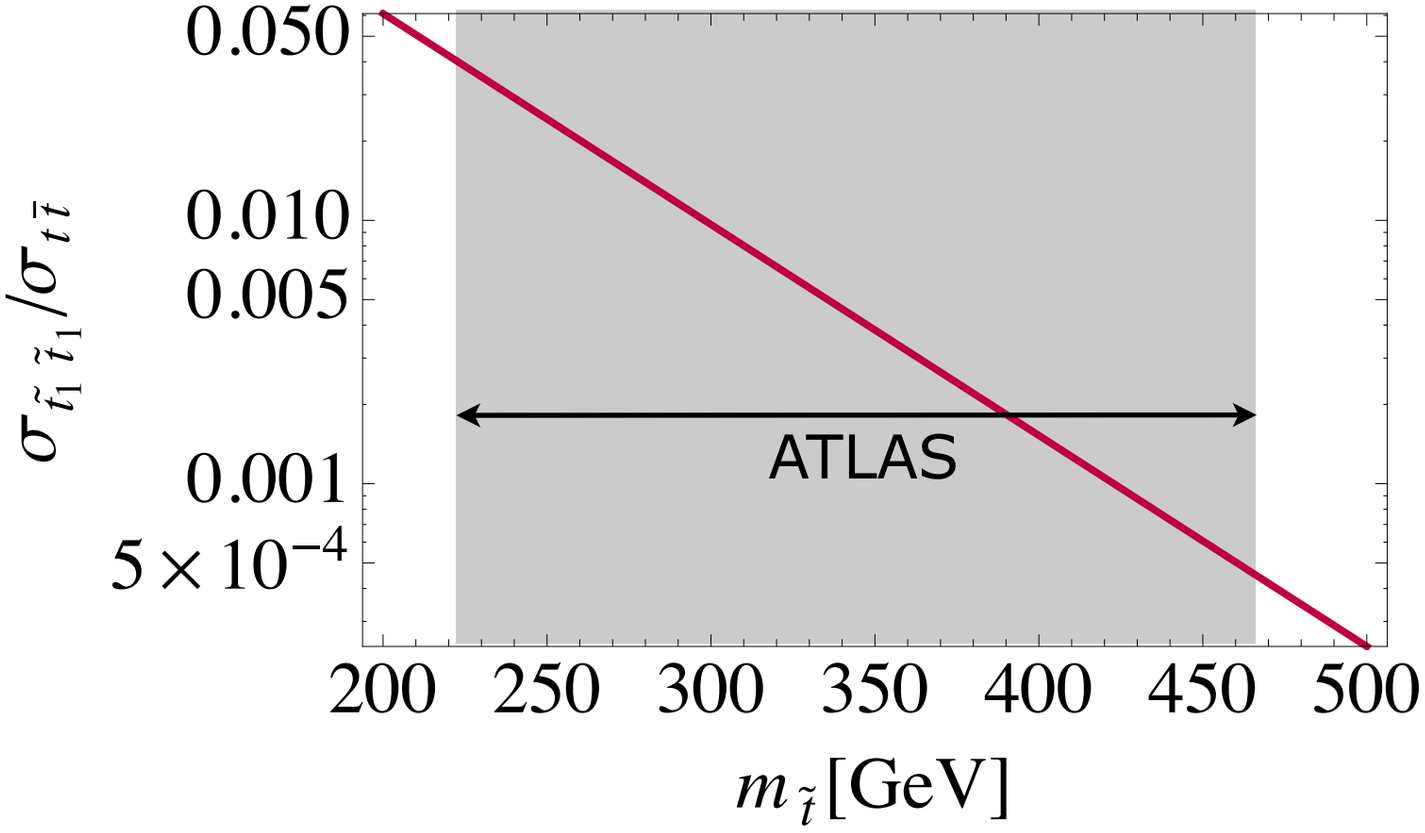
ATLAS+CMS combined



Lessons Learned

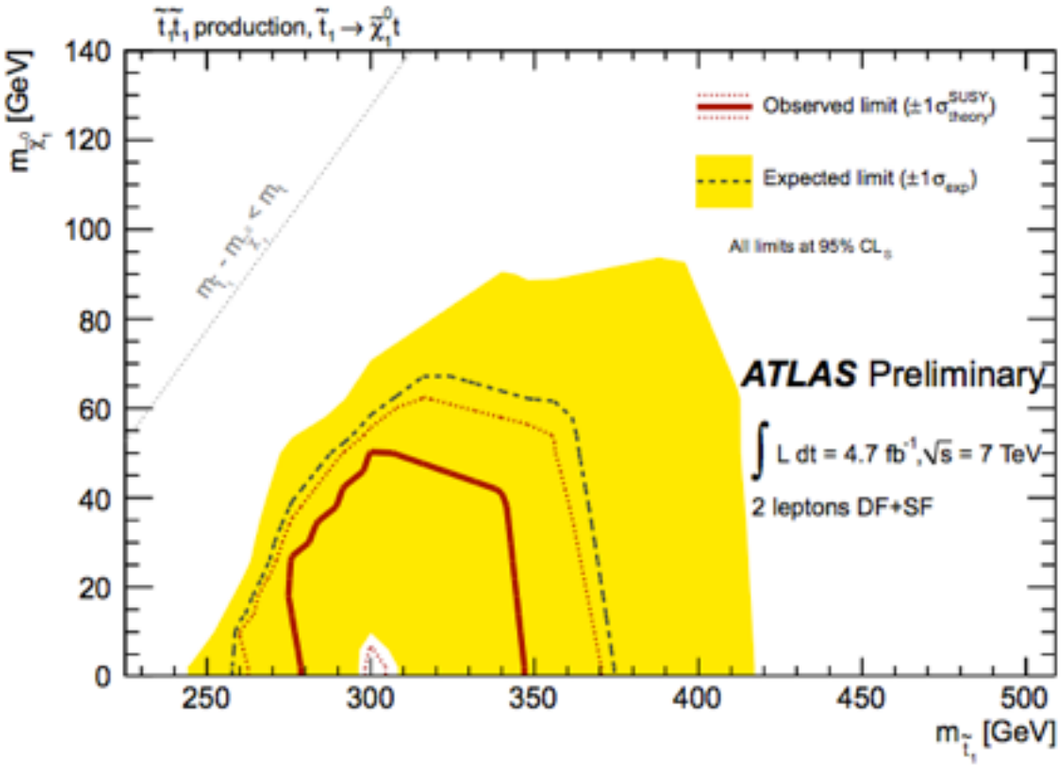


- ttbar challenging very for stop searches
- small signal cross-section

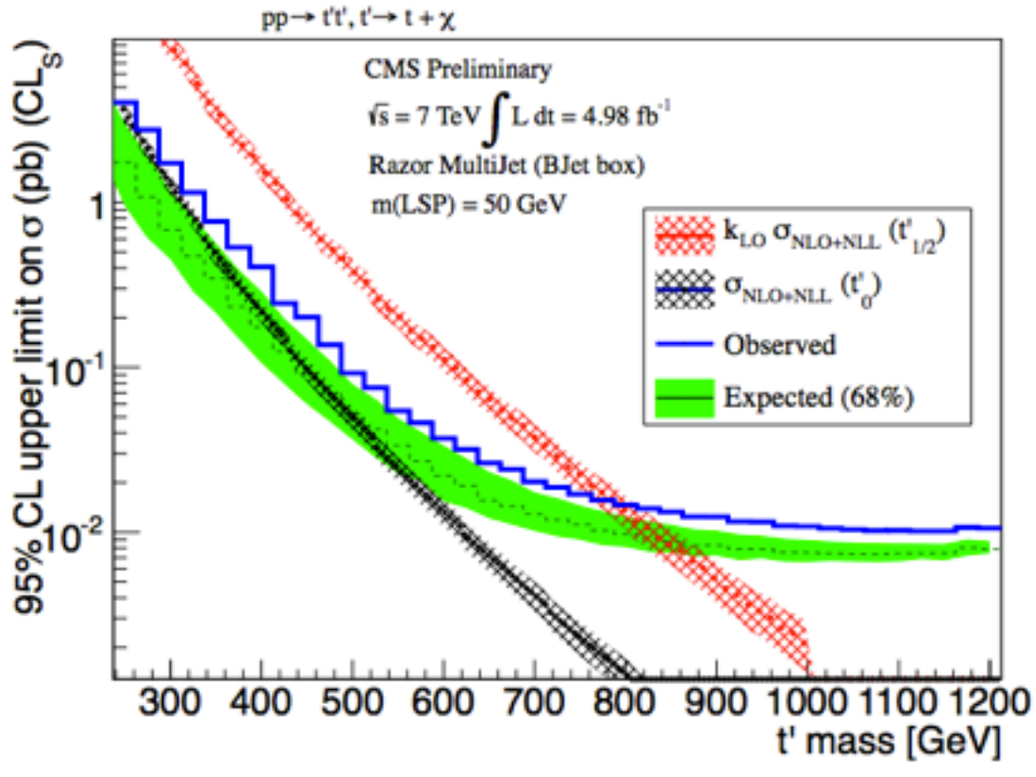


Lessons Learned

- ATLAS and CMS had to use really aggressive cuts
- turned limits vulnerable to background fluctuations and uncertainties in signal cross-section

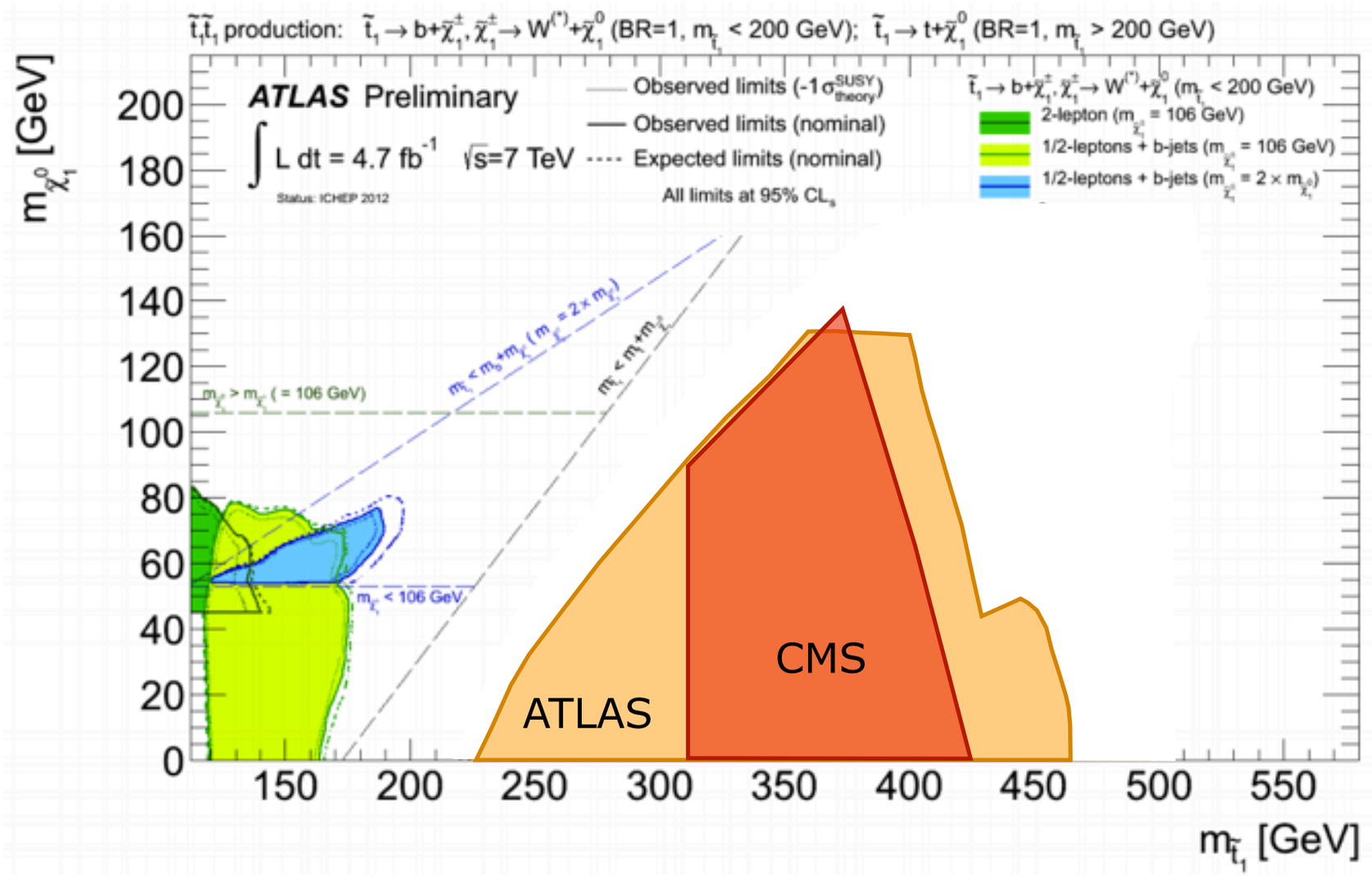


ATLAS dilepton search



CMS razor multijets

Lessons Learned



- still a lot of uncovered parameter space remains
- will likely require non-standard techniques

Recent activity among theorists

arXiv:1203.4813 *Bai, Cheng, Gallicchio, Gu*

Leptonic modes; new kinematic variables with endpoints

reach: $m_{stop} \sim 700$ GeV for light neutralinos

arXiv:1205.5808 *Han, Katz, Khron, Reece*

Rapidity differences and spin correlations

reach: light stops $m_{stop} \lesssim 200$ GeV

arXiv:1205.5816 *Kaplan, Rehermann, Stolarski*

Top-tagging for boosted tops from stop decays

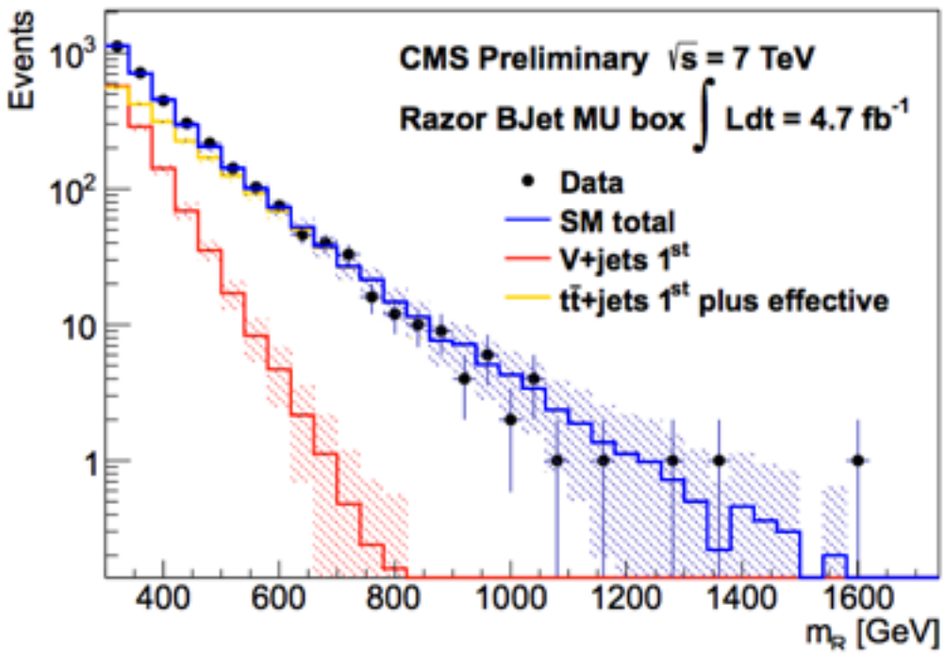
reach: $m_{stop} \gtrsim 300$ GeV

One more idea: Shape analyses

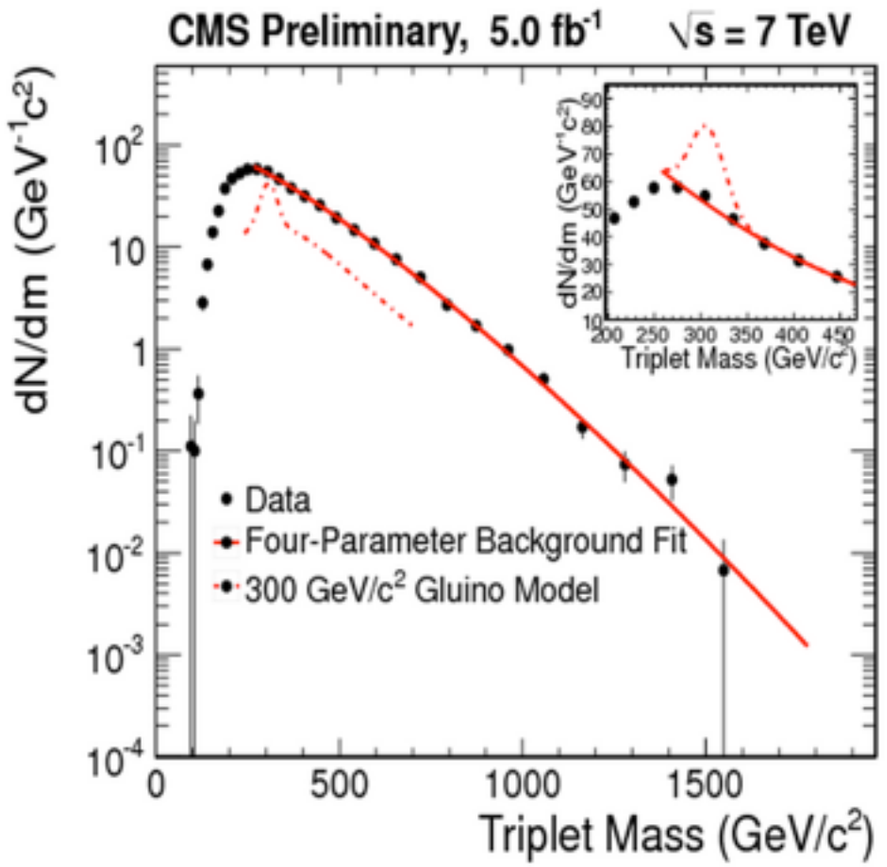
- challenging - backgrounds have to be very well understood
- not frequently used in SUSY searches

- successful implementations of it

Razor



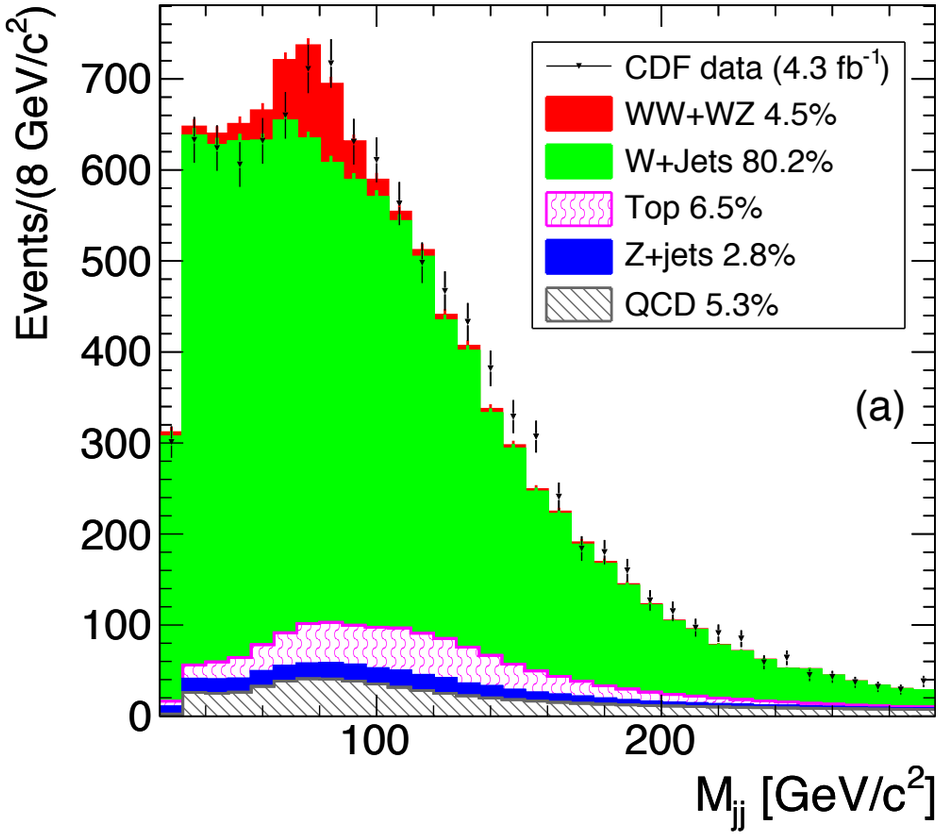
3-jet resonances (RPV gluino)

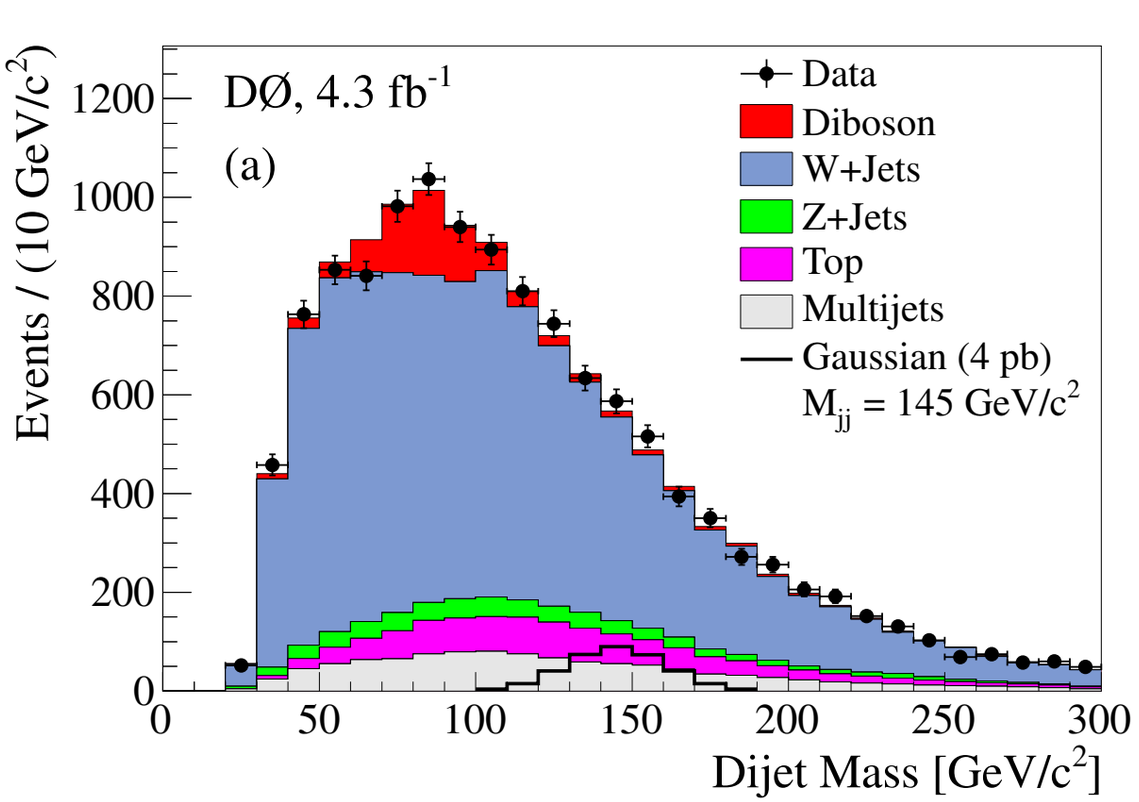


One more idea: Shape analyses

- challenging - backgrounds have to be very well understood
- not frequently used in SUSY searches
- not so successful....

Tevatron W+dijets



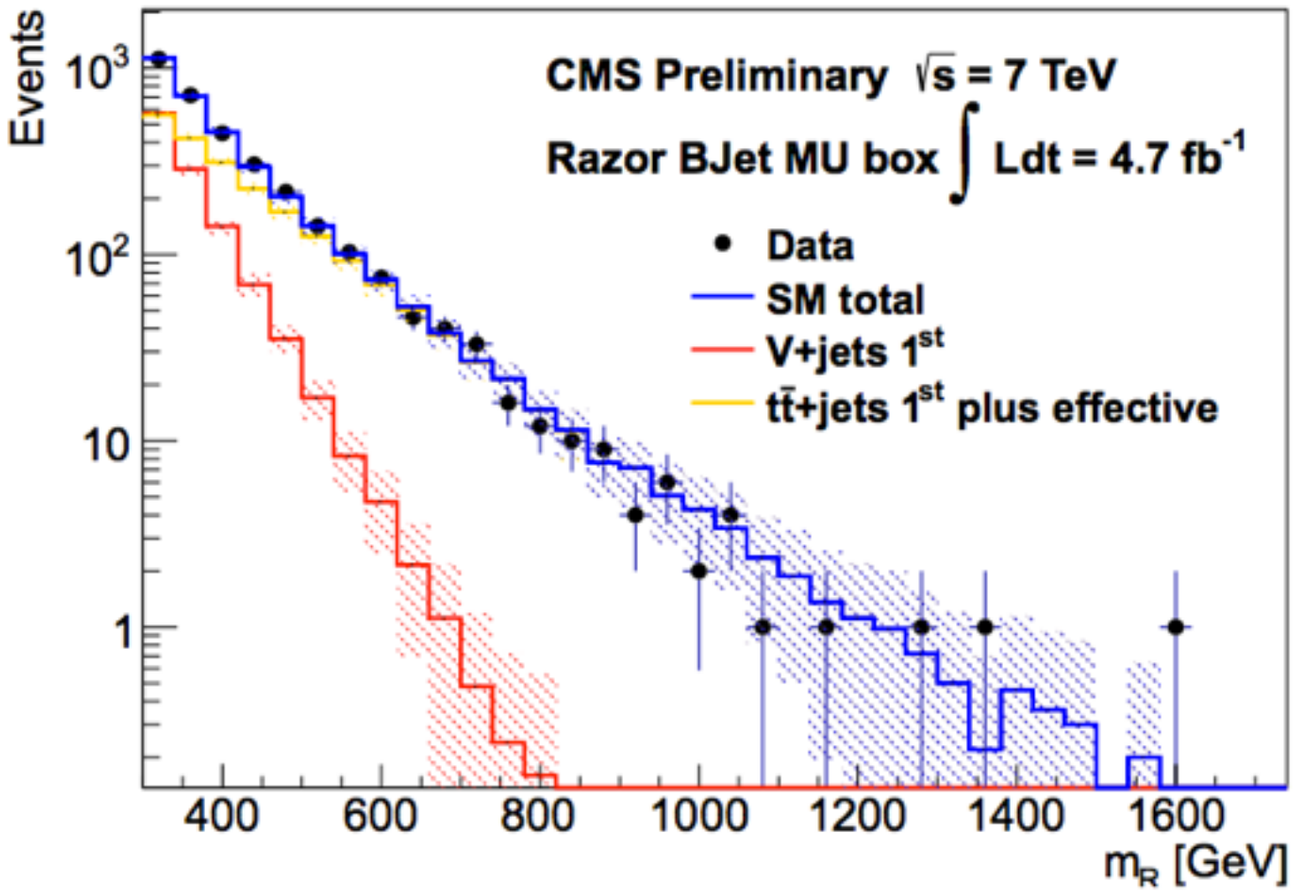


One more idea: Shape analyses

arXiv:1205.5805 Alves, Buckley, Fox, Lykken, Yu

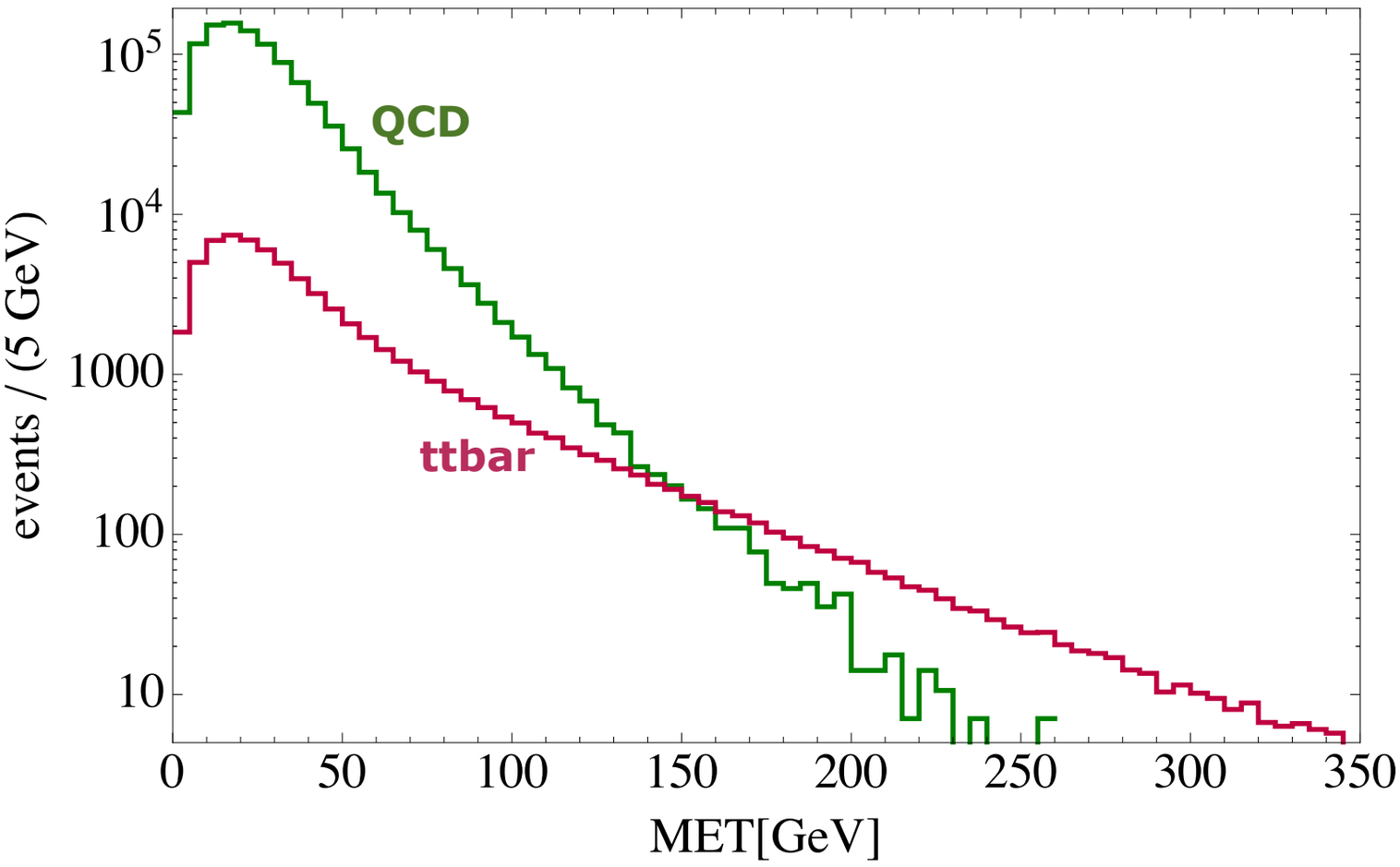
- MET shape in fully hadronic channel
- M_T shape in semi-leptonic channel

- inspired by razor analysis
  - modeling of background by simple analytical functions in certain regions of parameter space



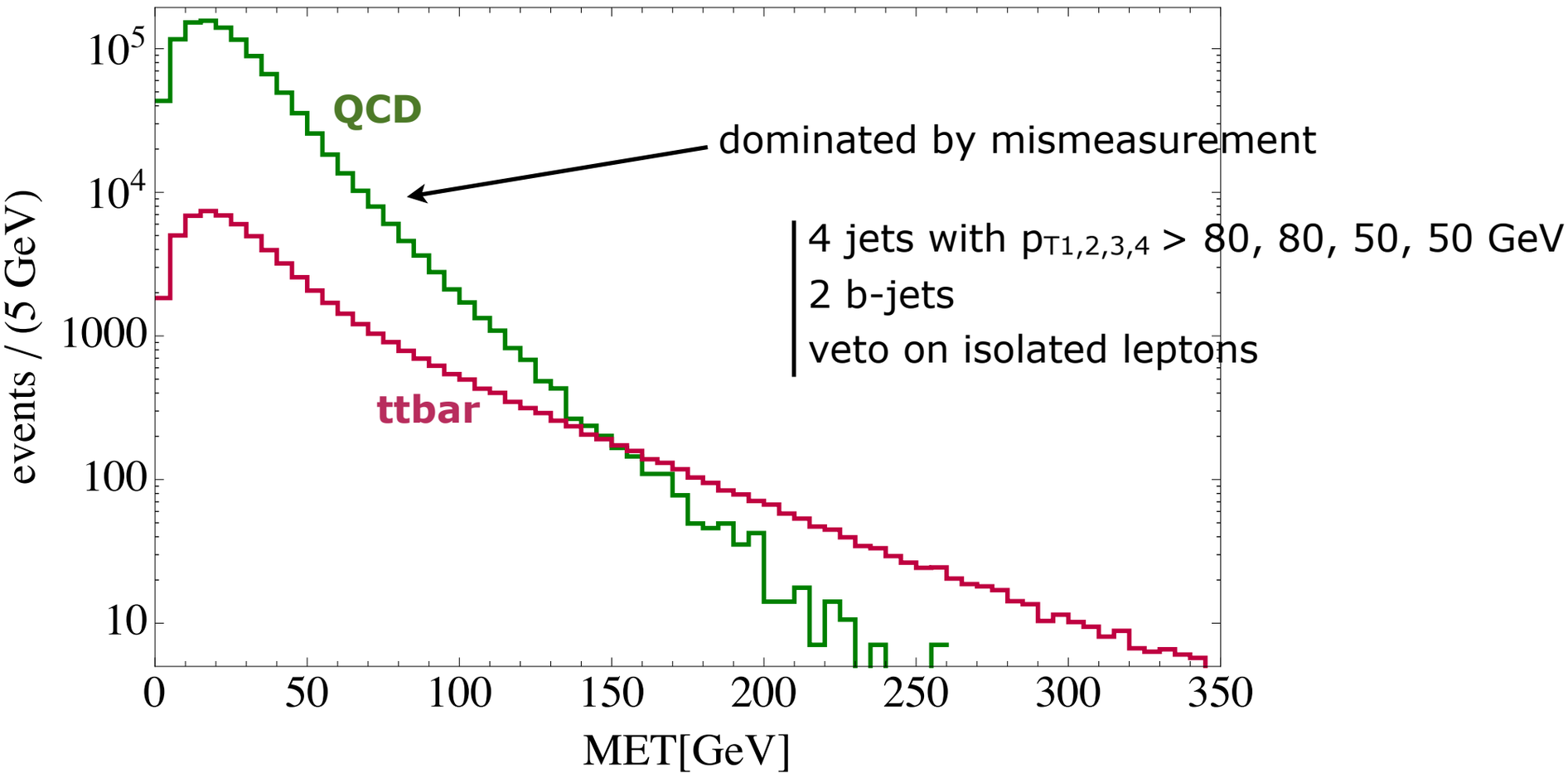
Hadronic Stops: MET shape

- main backgrounds: QCD and ttbar



Hadronic Stops: MET shape

- main backgrounds: QCD and ttbar



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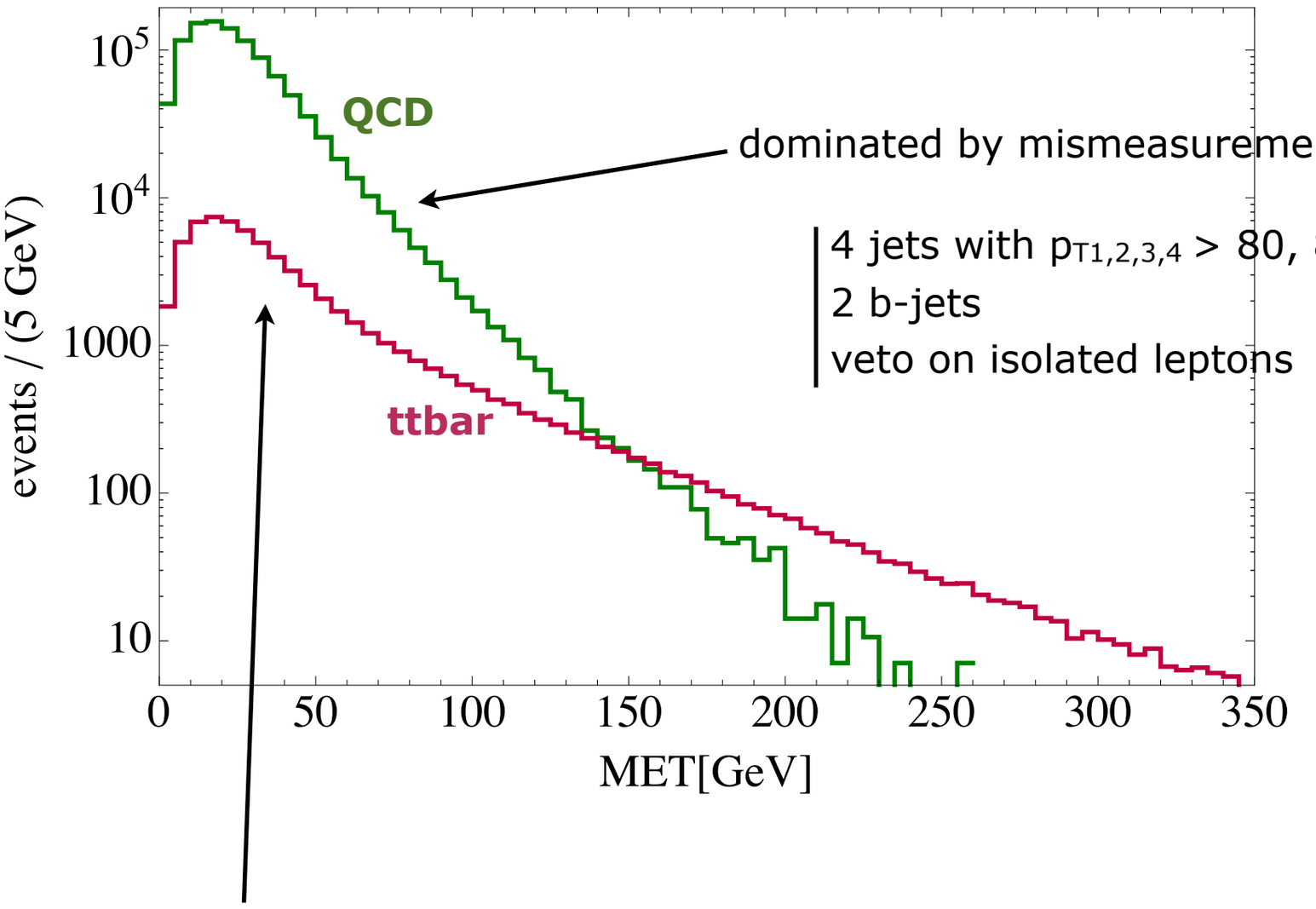
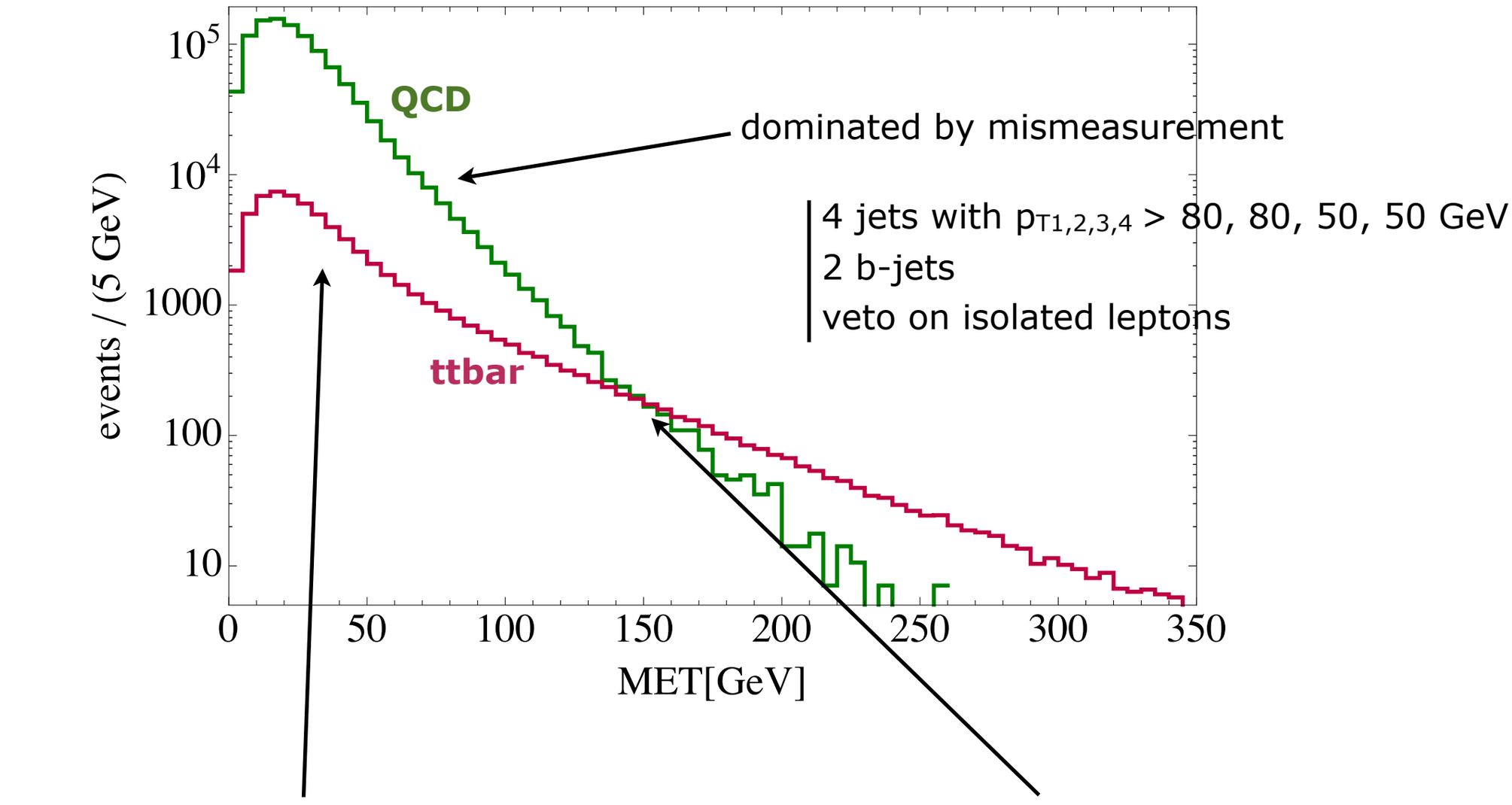
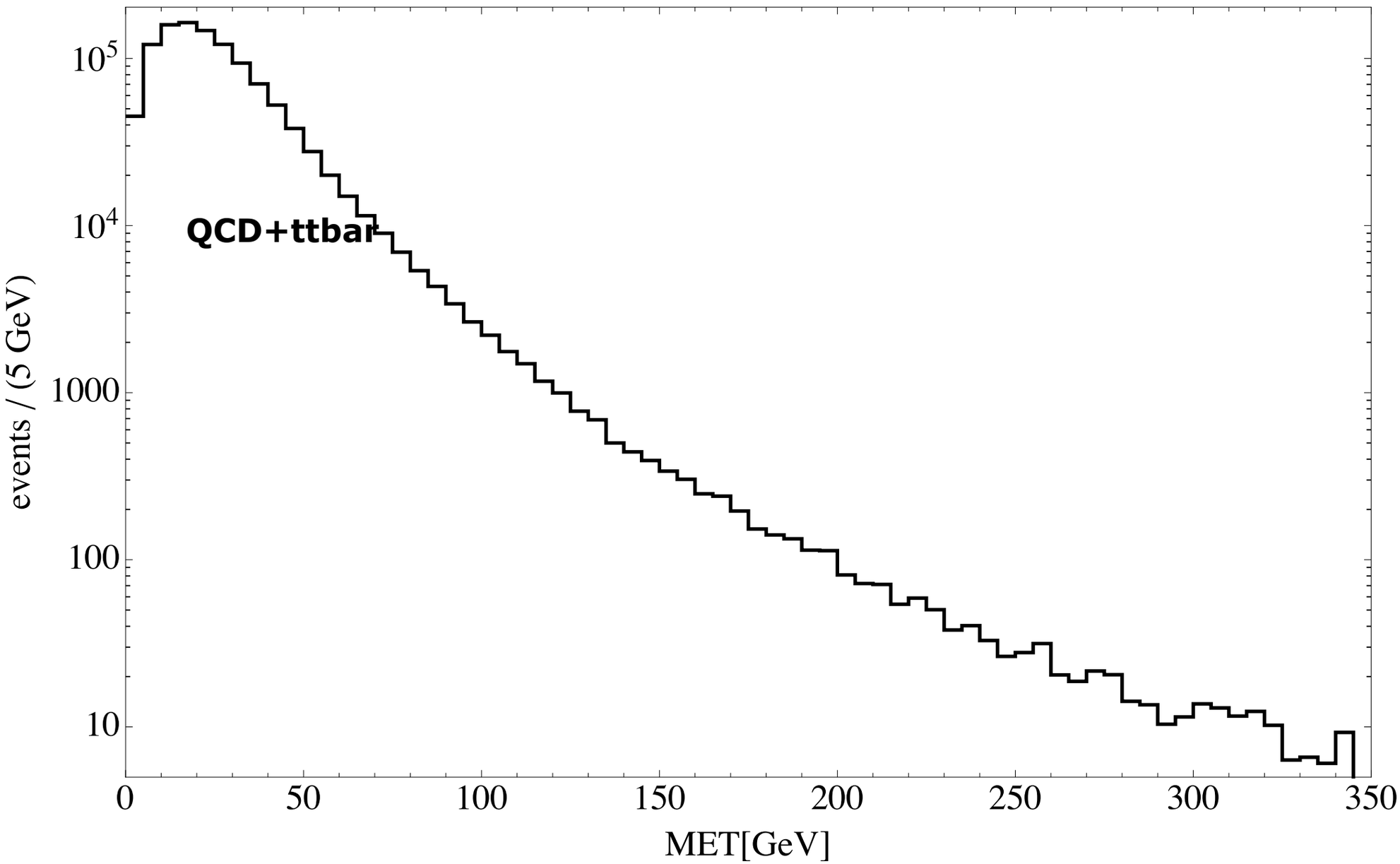


Hadronic Stops: MET shape

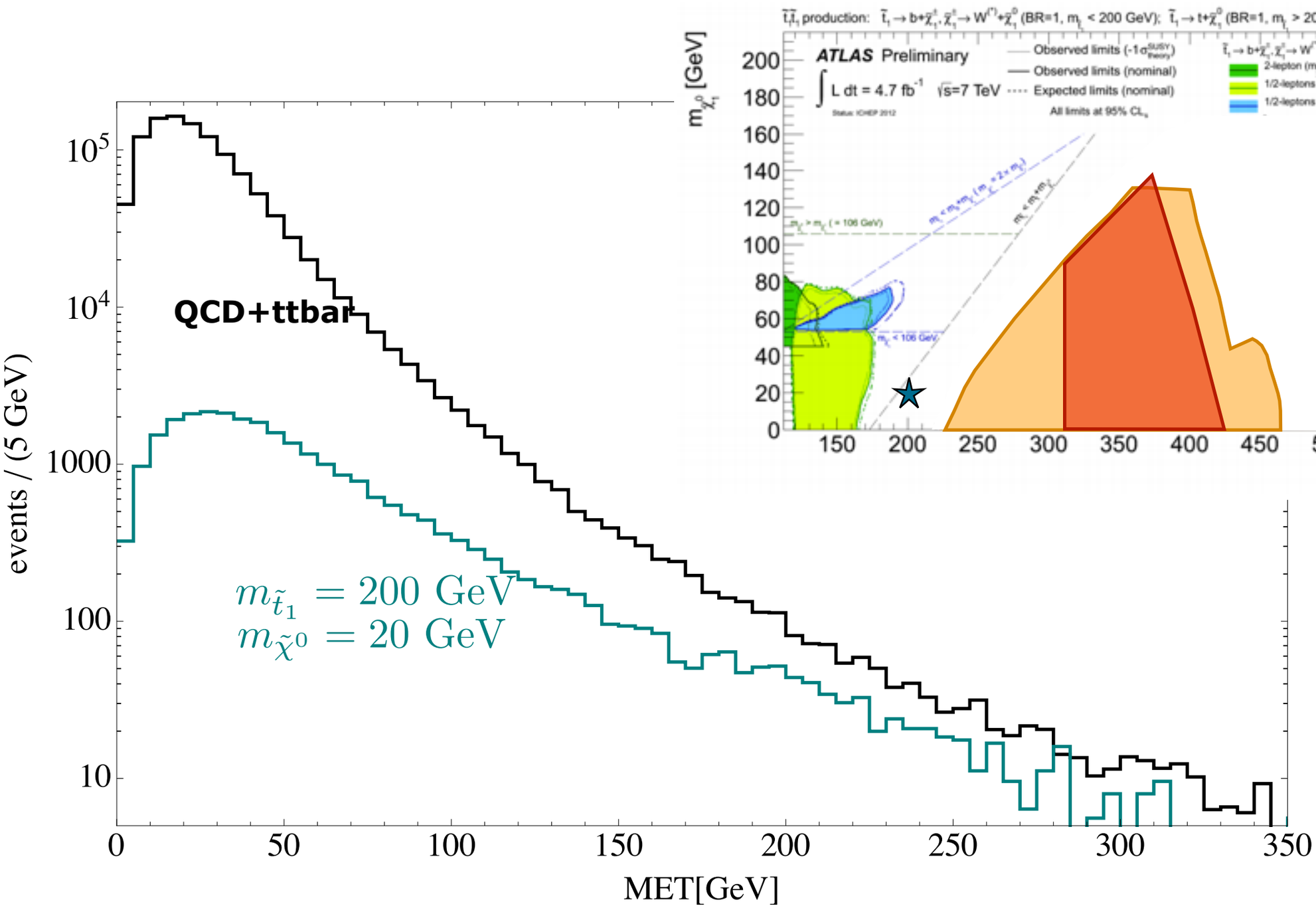
- main backgrounds: QCD and ttbar



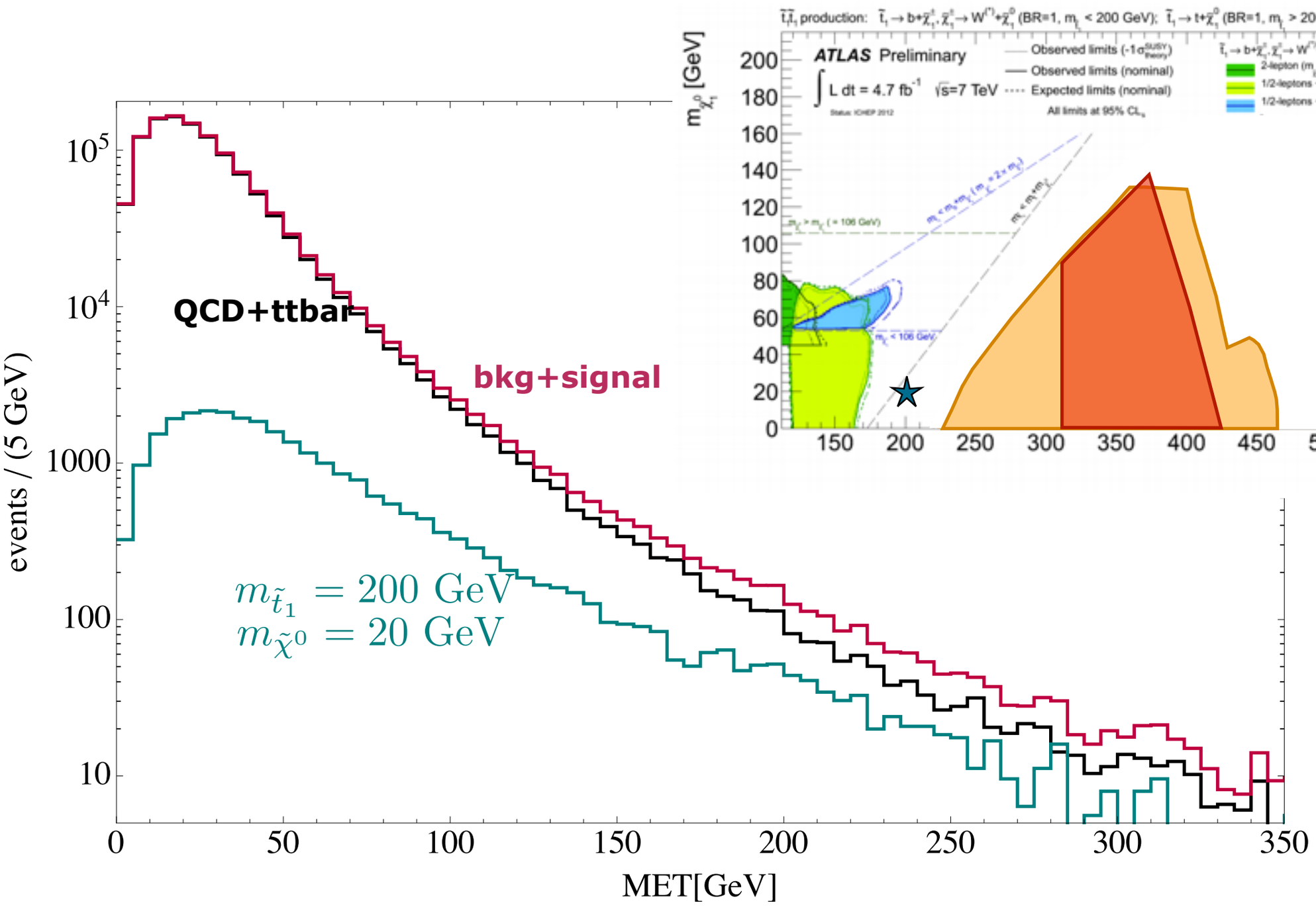
MET for background and signal



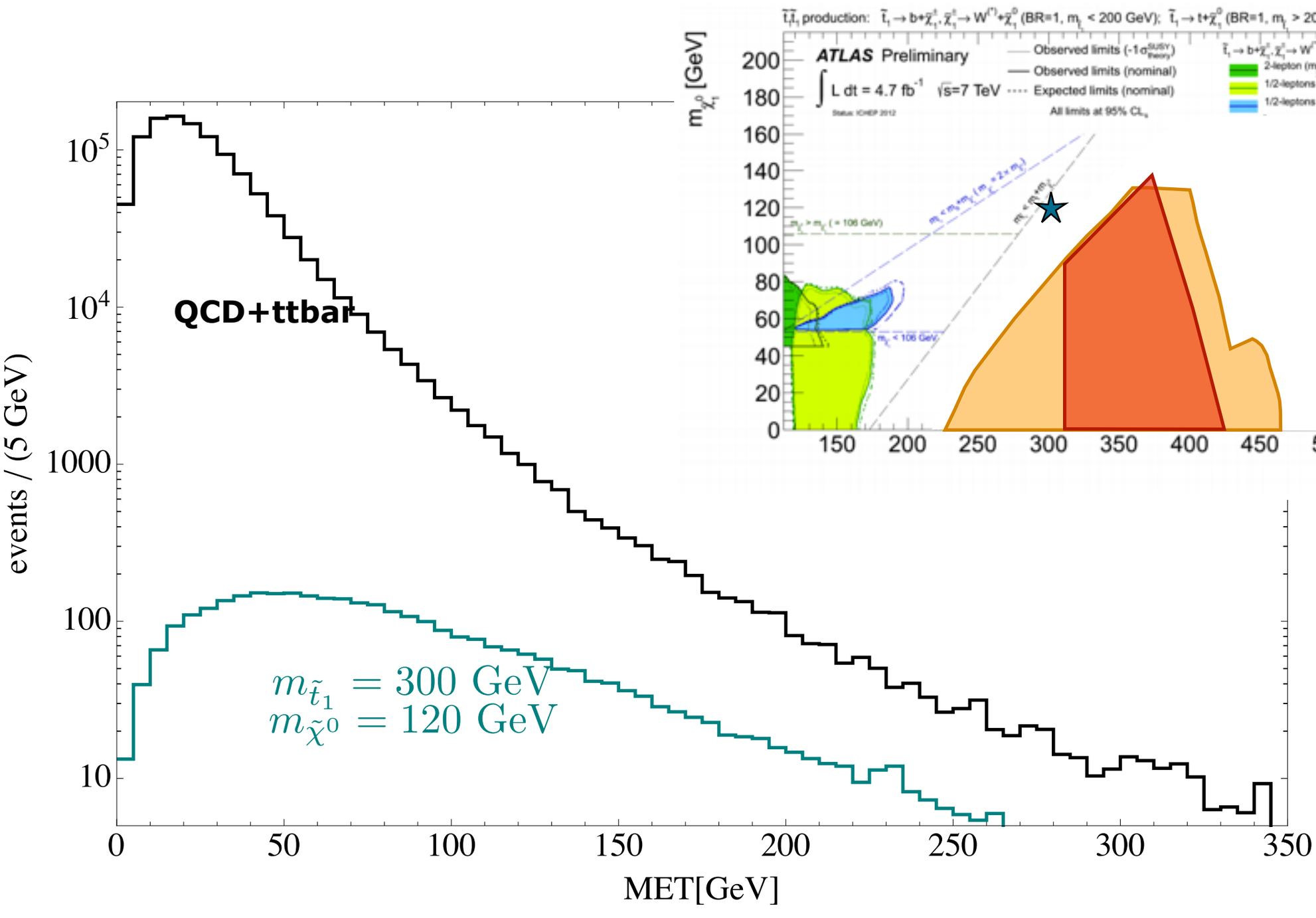
MET for background and signal



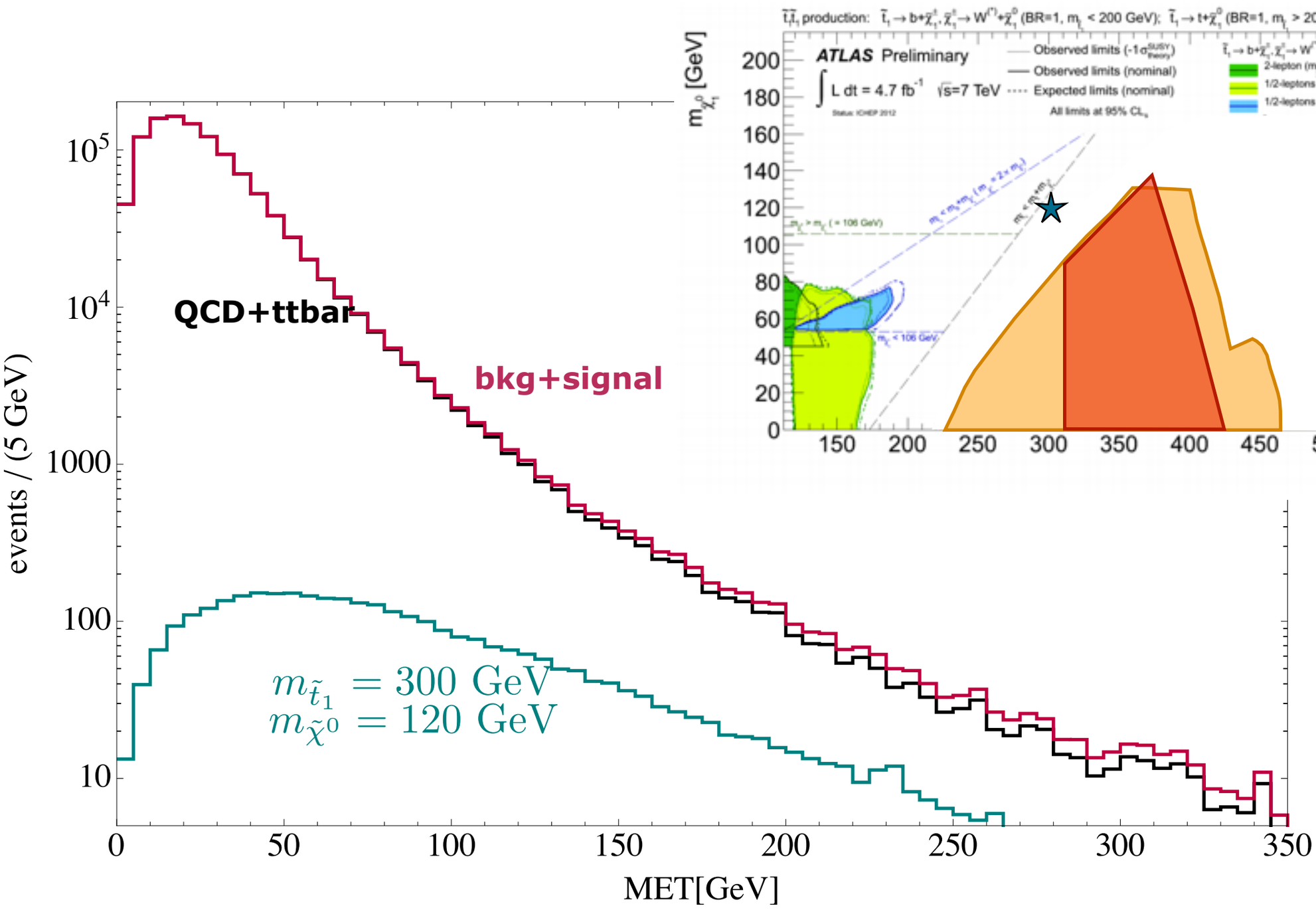
MET for background and signal



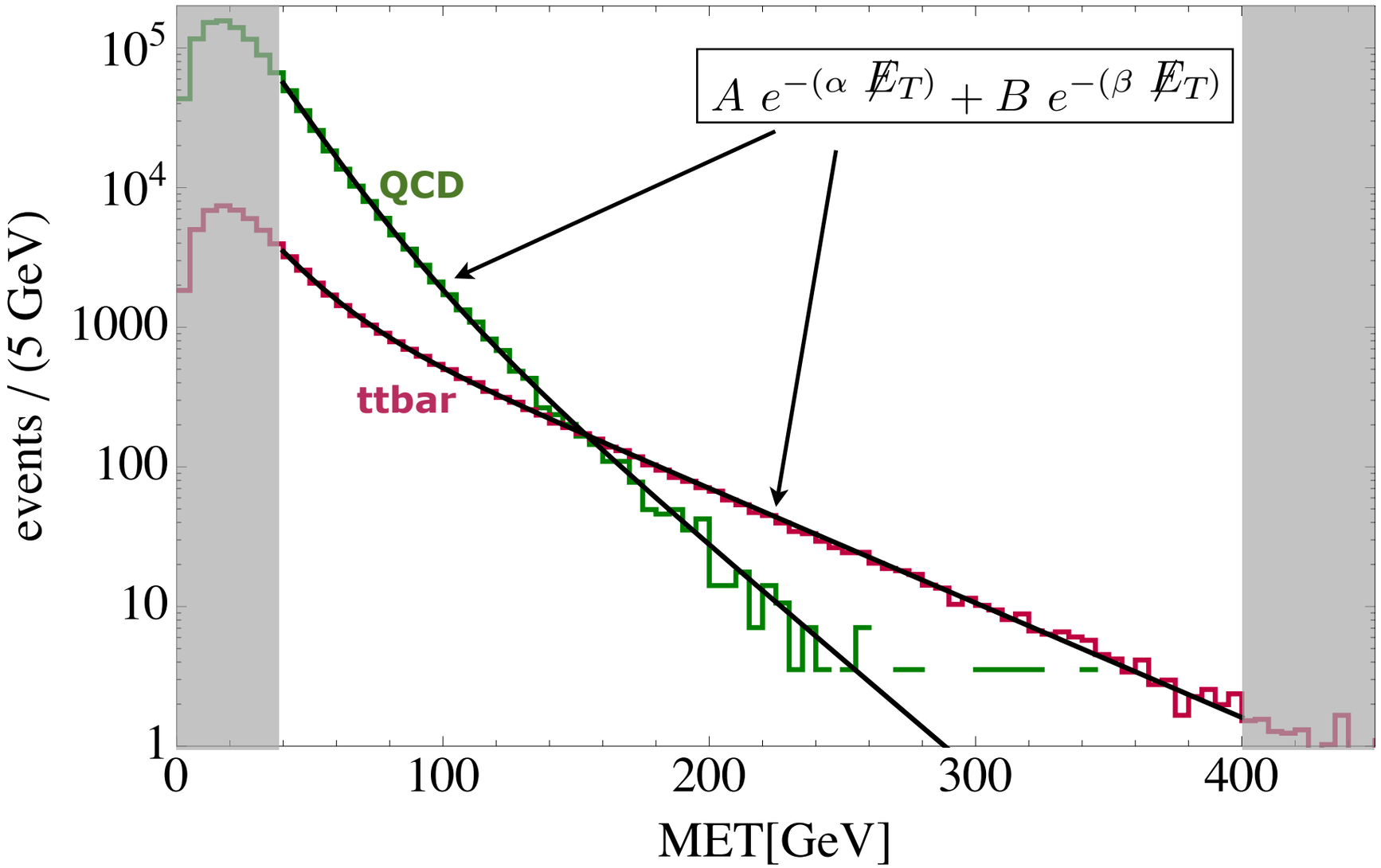
MET for background and signal



MET for background and signal

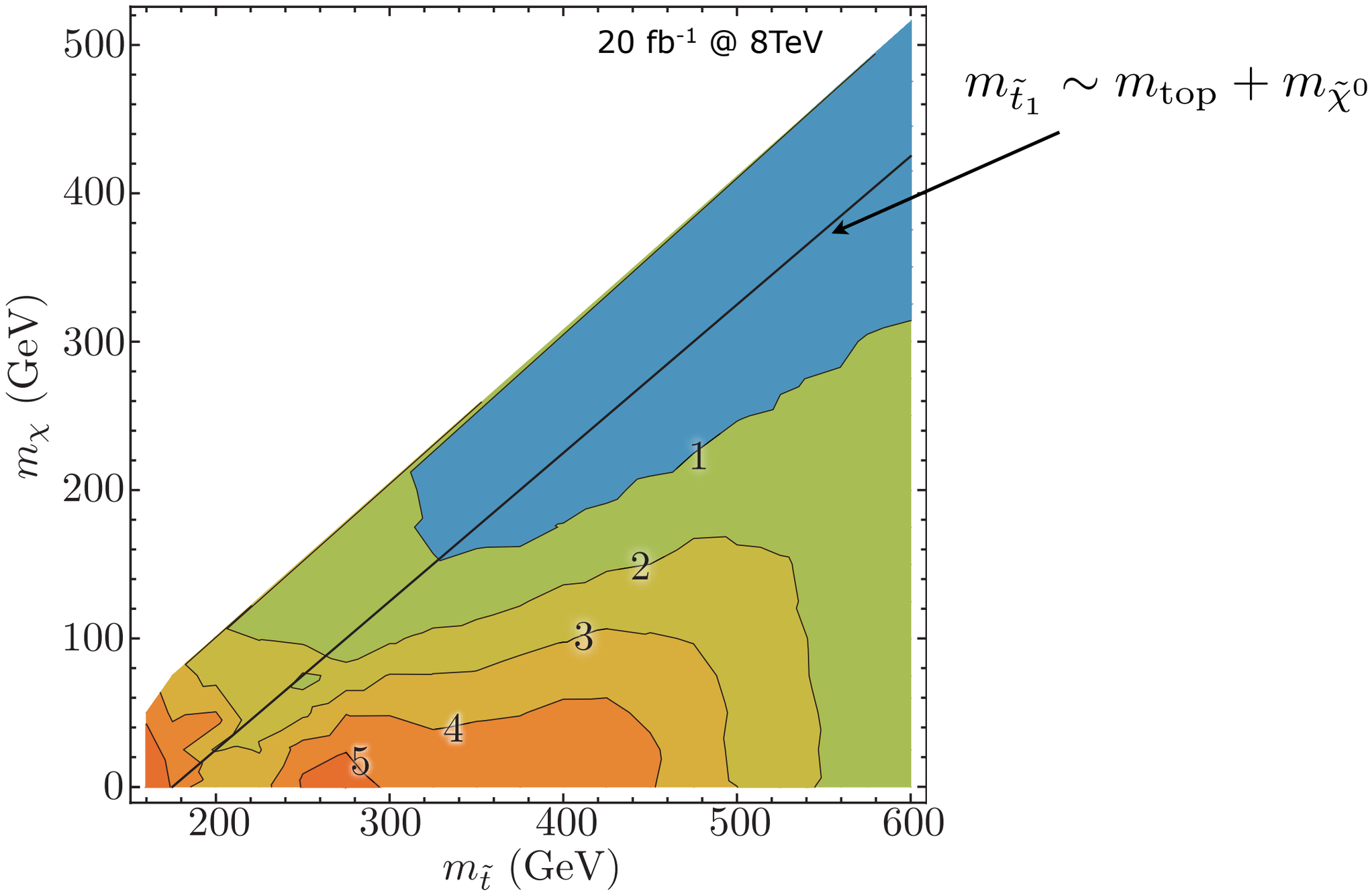


- analytic fit to both backgrounds, 20 fb^{-1} of MC @ 8TeV

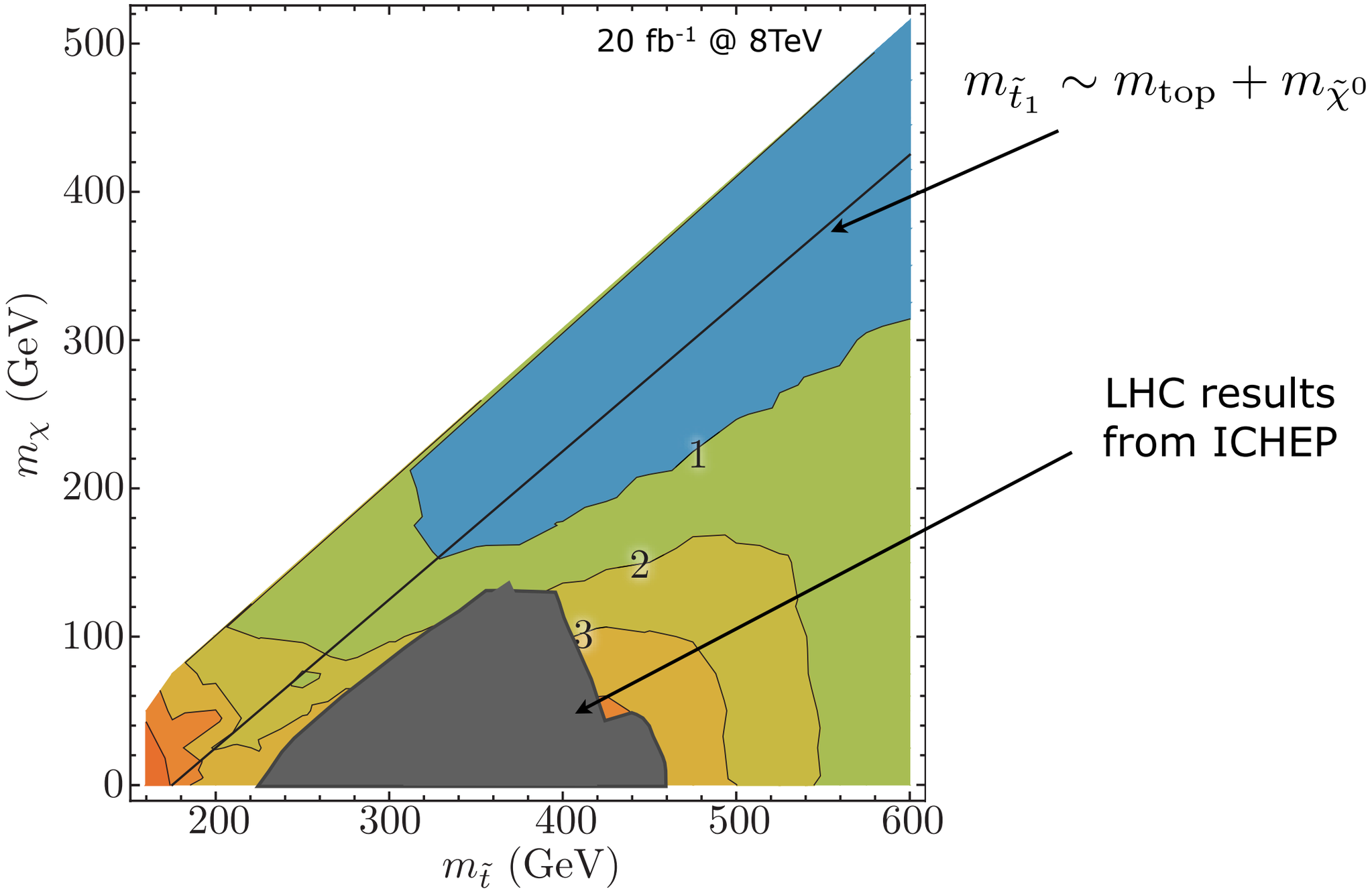


- generated 200 toys experiments with background hypothesis
- for each toy, extracted signal exclusion using binned likelihood
- included fit errors in likelihood
- to be conservative, ignored correlations between parameters

Expected exclusion reach for hadronic MET shape analysis

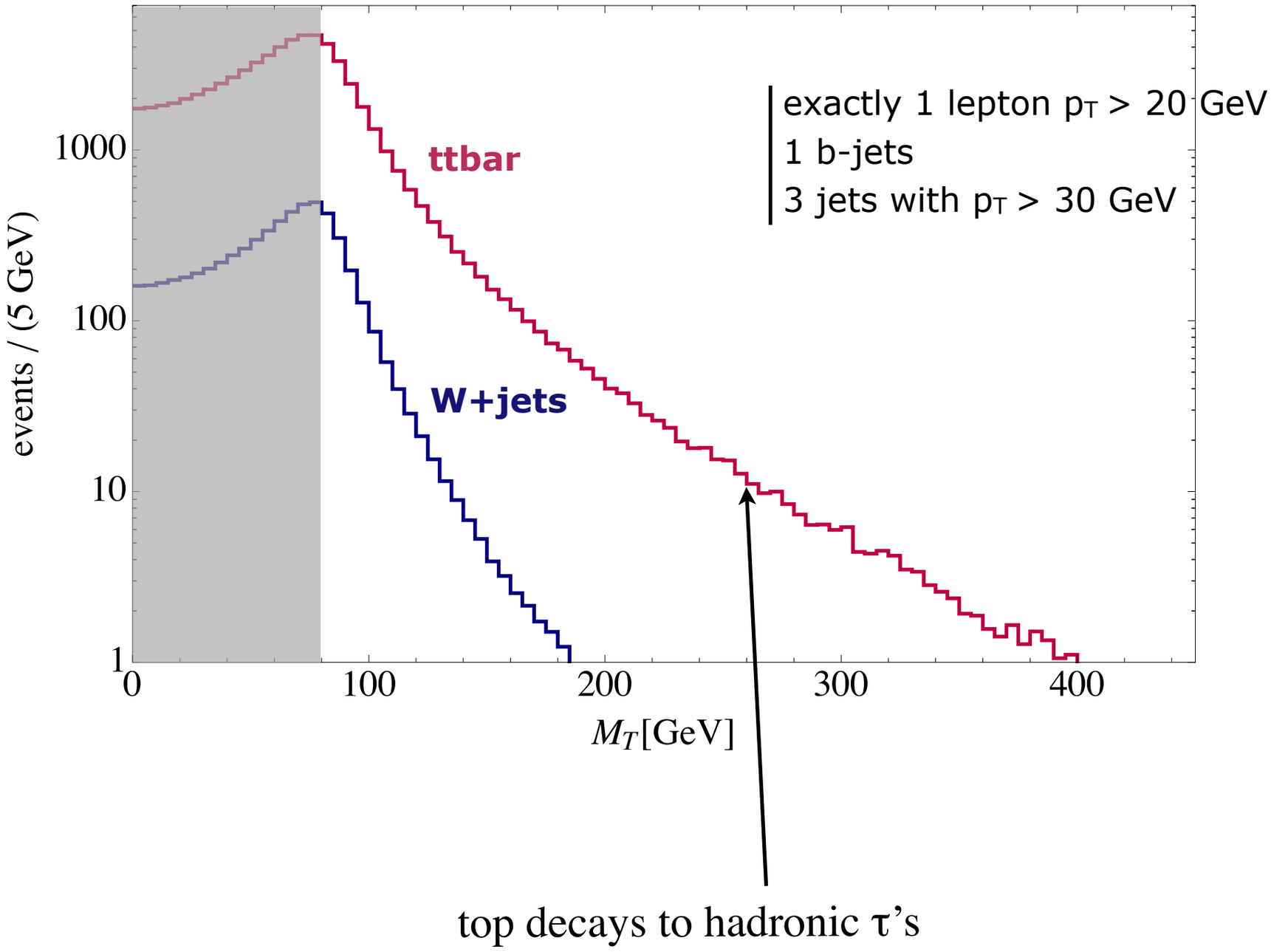


Expected exclusion reach for hadronic MET shape analysis



Semi-Leptonic Stops: M_T shape

- main backgrounds: ttbar and W+jets



Semi-Leptonic Stops: M_T shape

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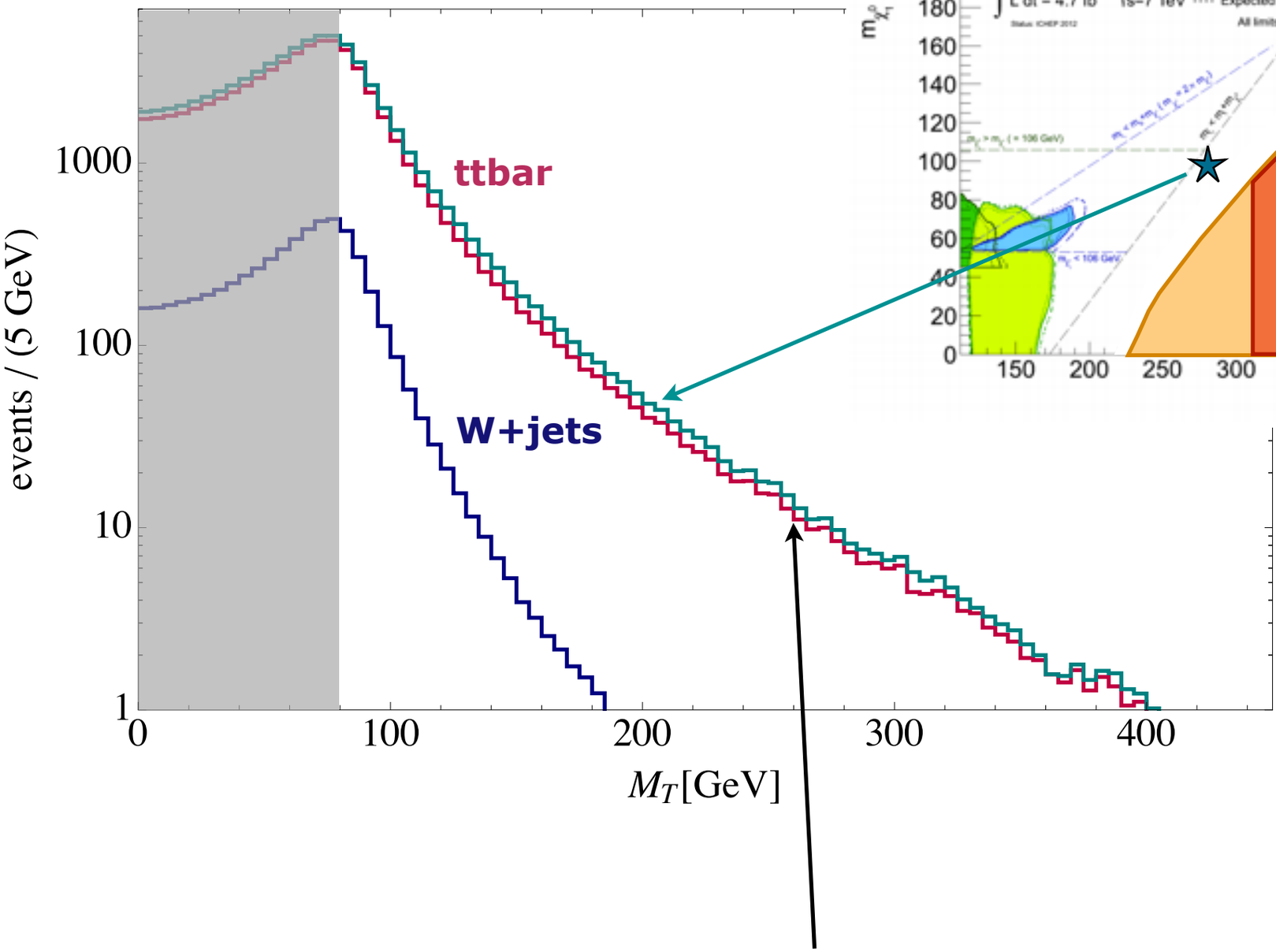
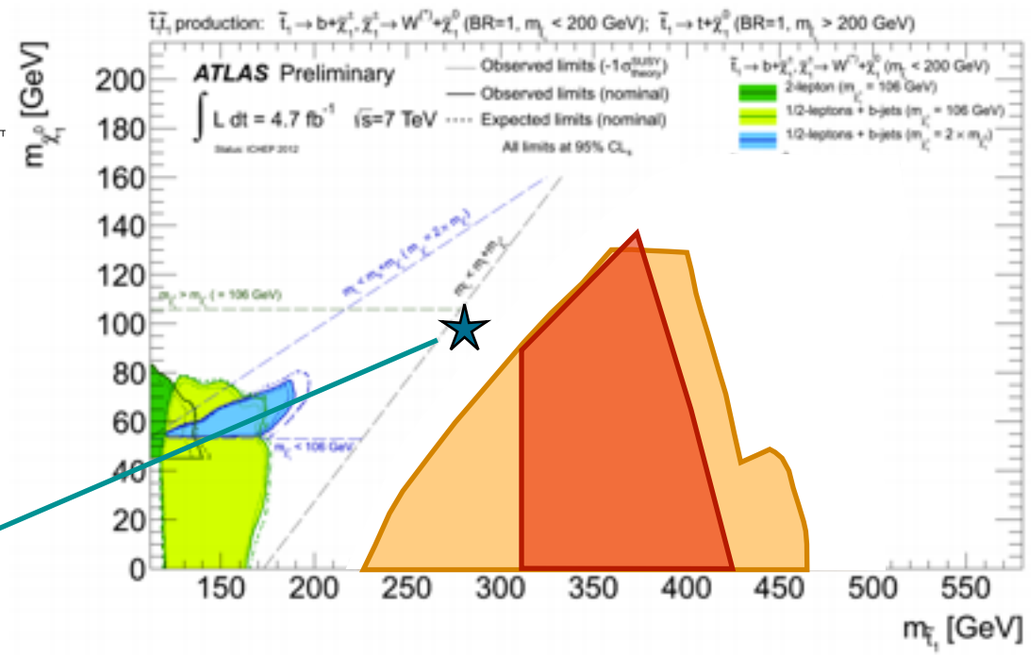
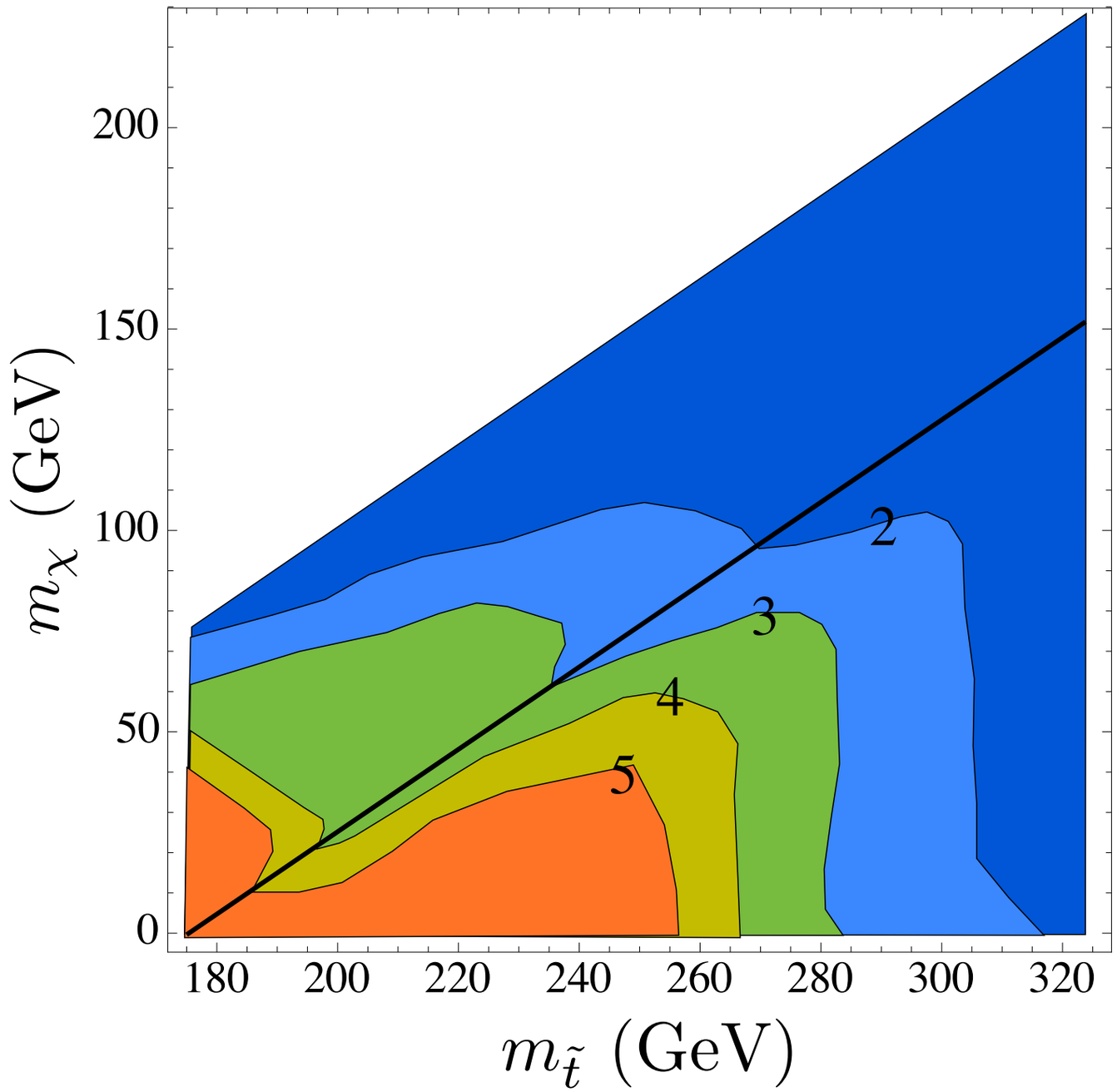


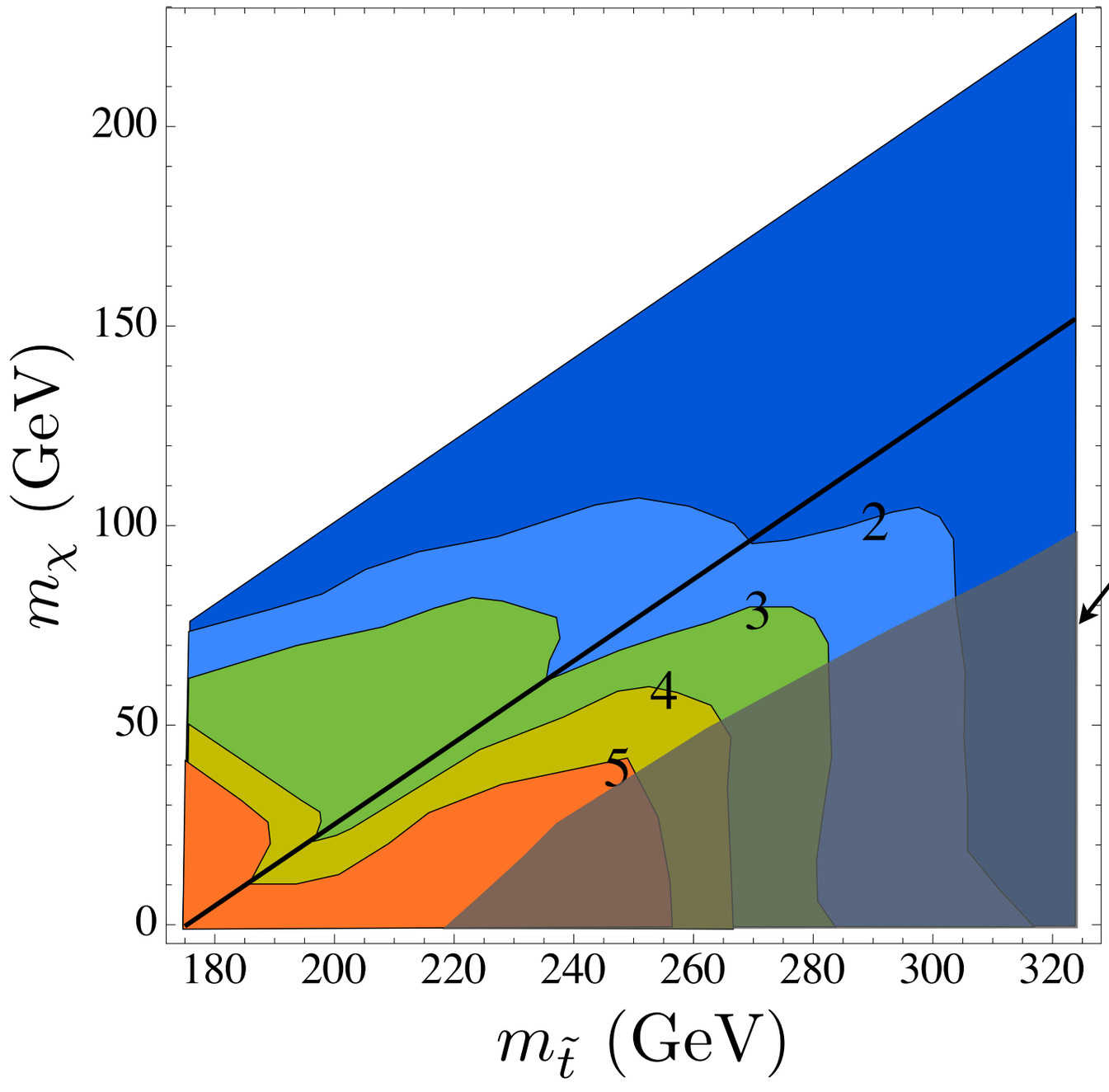


top decays to hadronic τ's

Expected exclusion reach for semi-leptonic M_T shape analysis



Expected exclusion reach for semi-leptonic M_T shape analysis



LHC results from ICHEP

Summary

- First LHC results for direct stop pair production
  - covered interesting regions of parameter space
- Challenging regions still allowed
- Attempt to explore the reach of shape analysis
- Could be useful for general new physics searches with MET